ARCHITECTURAL PRINCIPLES IN ARTHRODESIS

BY

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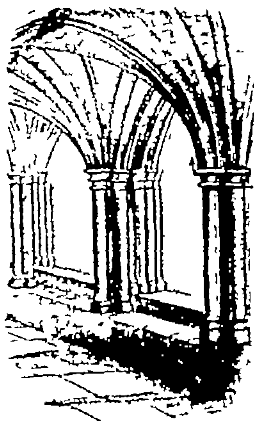
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With a Foreword by

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To

R. D. B.

PREFACE

THE results of orthodox methods of arthrodesis have been disappointing in my hands. In an analysis of these methods it was noticed that they followed no coherent plan, and the only factor common to all was the removal of cartilage from opposing joint surfaces, which is not always sufficient to produce fusion.

In an attempt to place the operation of arthrodesis on a sounder mechanical basis, I have employed certain elementary architectural principles. These principles are simple, but there has been some difficulty in utilising them within the anatomical confines of each individual joint. I have found that operations based on these principles give a higher percentage of successes, and I hope my experience may be of equal value to other surgeons.

Statistics of results for the hip joint only are given. I hope to publish those for other joints later.

I wish to acknowledge the debt which I, in common with other orthopædic surgeons, owe to that master of bone-graft surgery, Dr Fred Albee I should like to thank Professor Platt for his criticism and advice and for his great kindness in reading the proofs and writing a foreword; Professor Girdlestone for his encouragement and helpful suggestions at an earlier stage; Mr Humphrey Boardman, A.R.I.B A., for advice concerning architectural principles, my secretary, Miss M. Clark-Wilson, for her untiring patience and perseverance; my late House-Surgeon, Dr A. R. Hodgson, for his optimism and also for his help with the operation for arthrodesis of the elbow. Mr Macmillan of Messrs Livingstone has taken endless pains with the production, and whatever the matter, the form is surely difficult to criticise. Mr Douglas Kidd has not only drawn beautiful pictures but has given much sound advice. I am also indebted to Dr E. M. Churchward and Mr John Boyes for the compilation of the index and reading of the proofs.

I finish by paying a tribute to my " best friend and severest critic," Wing Commander H. Osmond Clarke. During my orthopædic career he has always been my mentor and stimulus.

H. A. BRITTAIN.

ALDERSHOT,
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FOREWORD

WHEN a joint is irreparably damaged by injury or disease the surgeon is often called upon to convert a painful or useless articulation into a comfortable stable ankylosis. The modern operation of *arthrodesis*, unlike the classical joint excision of the older surgery, does not aim at the direct eradication of disease. Fusion is the sole objective and the technique must be designed to attain this end. Indeed, in an arthrodesis for joint tuberculosis the diseased area is often deliberately by-passed and a fusion established outside the limits of the joint (extra-articular arthrodesis or para-articular arthrodesis). Formidable technical difficulties confront the surgeon in his attempts to fuse a joint. Every surgeon experienced in the field of bone and joint surgery has failed on many occasions to secure sound ankylosis. The chief reasons for failure, as the author of this monograph has pointed out, lie in a faulty conception of the mechanics of the operation Mr Brittain has sought for guidance in a study of architectural principles as applied to the use of the free bone graft, which he holds to be an essential part of the arthrodesis technique. Armed with these principles, he has devised and practised with success an appropriate type of arthrodesis for each joint The operations here described and so beautifully illustrated embody many novel and ingenious procedures. Mr Brittain's most notable contribution is his operation of ischio-femoral arthrodesis, in which Calvé's prediction that one day the tuberculous hip joint would be successfully fused by constructing a buttress on the adductor side of the joint has been fulfilled.

HARRY PLATT.

MANCHESTER,
December 1941

CHAPTER I

INDICATIONS FOR ARTHRODESIS

AT some stage in disease or degeneration of a joint the joint ceases to be an asset and becomes a liability. Loss of the articular cartilage may occur to such an extent that great pain and muscle-spasm are present, and the value to the patient of what residual movement is left may be far outweighed by the pain this movement causes From this stage onwards, with few exceptions, no matter what general treatment for the actual disease is undertaken, permanent immobilisation of the joint is the end-point in view, either by external apparatus or by arthrodesis (The exceptions are, of course, those few joints in which it is possible to perform a successful arthroplasty)

FUNCTION AFTER ARTHRODESIS

The function of a patient with a fused joint is surprisingly good Gradual increasing limitation of movement has tended to mobilise supplementary joints, so that these have had a preliminary warning and are ready to take an additional strain. Muscle-spasm may limit movements, not only of the diseased joint but also of other joints in close proximity, and the elimination of muscle-spasm may actually make the patient more mobile. The main advantage of fusion lies in the relief of pain. Constant pain may render the patient reluctant to use the joint or to take weight, and restrict the function of the entire limb to a minimum.

A psychological reaction may arise which causes a reflex inhibition of function because of pain Consequently a great disparity may exist between the passive movement elicited in the joint on clinical examination and the actual function which is present in practice. Removal of this pain will eventually abolish this inhibition, so that the function of the limb becomes actually greater It is unusual for patients after arthrodesis to complain that their joint is stiff and that they wish it were

movable.[1] One reason for this is that their capacity for movement has increased because of the removal of pain and muscle-spasm.

An additional advantage is the improvement in general health which occurs. No one can fail to have been struck by the change which gradually occurs in the facies of the patient whose arthritic joint has been put at rest either by an arthrodesis or by immobilisation in plaster of Paris. The haggard, drawn look gradually disappears, to be replaced by an appearance of tranquillity and sleekness which is undoubtedly due to the relief of pain.

In bilateral arthritis fusion of one joint, preferably the worse, may allow the patient to nurse the other and delay or halt the progress of arthritis there. Fixation may, of course, be disadvantageous for those in special occupations, and this must always be borne in mind, especially in wage-earners.

INDICATIONS FOR ARTHRODESIS

These are as follows :—

1. Tuberculous Arthritis.
2. Infective and Rheumatoid Arthritis.
3. Osteo-arthritis, in which is included Degenerative Arthritis as the result of Trauma.
4. Paralysis—Infantile, Spastic and Traumatic.
5. Congenital Deformities such as Neglected Congenital Dislocation of the Hip, Club-foot and Congenital Subluxations of Joints.

cartilage is eroded and the joint disorganised, ankylosis only is to be hoped for.

2. **Infective and Rheumatoid Arthritis.**—In these affections the damaged joint may fuse without surgical interference, and the ankylosis may be bony. There is no guarantee, however, that this will take place, and even after prolonged immobilisation a few degrees of painful and useless movement remain. The time factor may be of importance. These joints are easier to fuse than in tuberculous arthritis, and operation can be undertaken at an earlier stage with a corresponding shortening of the patient's period of immobilisation. Once there is no hope of a mobile painless joint resulting there is no reason for postponing arthrodesis.

3. **Osteo-arthritis.**—In osteo-arthritis a more difficult decision has to be made. One is frequently surprised by the radiographs of osteo-arthritic joints showing gross arthritis in joints which are causing comparatively little pain. The course of the disease is punctuated by acute exacerbations with occasional long remissions. During the remissions one would hesitate to destroy a joint with apparently fairly free movement and causing but little disability, while during the acute exacerbations one might have no hesitation in doing so. It is wise, therefore, to examine the patient over a period of time before proceeding straight away to arthrodesis.

As the result of *severe trauma* the problem is easier for the following reasons :—

(*a*) **The Joint may be completely Destroyed,** leaving no useful alternative to arthrodesis.

(*b*) **The Joint may Improve.**—It may be impossible at the time of injury to decide how painful a joint will result. A reasonable trial of function should be allowed to discover this. It is surprising how joints, apparently grossly disorganised, will recover. Irregularities and "steps" in the joint surface may become filled in and cause no symptoms, giving many years of useful function.

(*c*) **The Joint may Degenerate.**—Degeneration may take place steadily as the result of trauma, and successive radiographs will show the rate of degeneration. Operative treatment may then become inevitable.

In osteo-arthritis of the hip joint various competitive procedures may be of value in individual patients and for individual stages of the disease, such as manipulation, subtrochanteric osteotomy, reconstruction operations or acetabuloplasty.

4 **Paralysis—Infantile, Spastic and Traumatic.**—*For infantile paralysis* fusion of flail joints may be essential, the most frequently performed being stabilisation of the foot in the flail or "dangle-foot," and arthrodesis of the shoulder when the function of the hand and elbow is good

Arthrodesis of the hip may be contemplated in complete gluteal palsy where a severe strain is thrown on the lumbar spine. In considering fusion of joints in the flail limb, one must not forget that a long lever will have been made consisting of atrophic or undeveloped bone which will fracture easily

In spastic paraplegia stabilisation of the deformed foot is frequently beneficial, and arthrodesis of the first carpometacarpal joint may be performed to counteract adductor spasm of the thumb, and to fix it in the position of maximum function

In nerve injuries fusion of joints is only occasionally indicated, viz., the shoulder in brachial plexus palsy resulting in a flail shoulder, and stabilisation of the foot in external popliteal paralysis. It is advisable to wait until one is certain that permanent paralysis is present It is not unknown for nerves to have recovered after premature arthrodesis, indicating that rest in the optimum position is an important part of the treatment of paralysis

5 **Congenital Deformities.**—There is a strong case for the treatment of neglected congenital dislocation of the hip by arthrodesis, as will be discussed later Degenerative arthritis is frequently present, and other operative procedures such as osteotomies of the Shanz or Lorenz type, or even the formation of a shelf, are probably only palliative, and do not relieve pain completely in every patient

The Naughton Dunn or Hoke operation is very successful in the correction of the neglected club-foot It is surprising how long the arthrodesed foot continues to function without pain or disability.

CHAPTER II

CAUSES OF FAILURE OF ARTHRODESIS

ARTHRODESIS in the presence of disease may be extremely difficult, if not impossible, and the failure of an attempt at fusion may make the patient's condition worse. *In tuberculosis*, post-operative sinuses, secondary infection or even the spread of disease through the removal of local barriers of resistance may occur. *In osteo-arthritis* there may be an increase of pain and deformity if fusion does not result. At the best, the patient has been subjected to the trial of an operation and the immobilisation following without the relief of symptoms. It is of the greatest importance, therefore, to examine carefully the various causes of failure, and where possible to eliminate them.

The chief causes of failure of fusion are as follows :—

1. **Inadequate Apposition.**
2. **Inadequate Immobilisation.**
3. **Extension of Disease.**
4. **Operations Based on Faultily Conceived Mechanical Principles.**

1. Inadequate Apposition.—Opposing joint surfaces, when denuded of cartilage, do not tend to grow together and fuse with the eagerness with which a fractured bone, properly treated, unites Furthermore, normal joint surfaces are accurately apposed, and the removal of cartilage distorts this apposition. In performing intra-articular arthrodesis the surgeon is constantly faced with the difficulty of fitting a structure which has been greatly reduced in size, like the head of the femur, into a cavity which has been greatly increased, like the acetabulum. Similarly, in arthrodesis of the ankle joint the tibio-fibular mortise becomes much too large for the reception of the astragalus. This difficulty of accurate apposition requires careful shaping of the opposing

joint surfaces, a precaution frequently neglected. Even, however, with the most accurate apposition a joint may still fail to fuse, and this most frequently if the additional support of a bone graft has been omitted. A graft, if traversing the joint, stimulates bony union throughout its course, and if placed in the position of maximum support, helps to immobilise the joint while extra-articular fusion is taking place. It is most strongly advocated, therefore, that in performing an arthrodesis a graft should be used in every case, with the possible exception of children where the piercing of epiphyses by grafts may result in possible disturbance of growth.

2. **Inadequate Immobilisation**—Inadequate immobilisation is a source of failure in arthrodesis, even as it is a cause of non-union in fractures Plaster casts must immobilise the joint completely, eliminating all movement. Provision should be made for wasting of muscles and changes in position due to gravity or the prevailing muscle pull, as, for example, adduction and external rotation at the hip, and adduction at the shoulder.

Repeated changes of plaster should be avoided as far as possible, as the movement, which will occur, discourages bone formation. If a plaster has to be changed the greatest care must be taken to place the joint in the same position as before If correction of position has to be undertaken, it should be done early, *i.e.*, in the first three weeks, and rarely after six weeks. The joint must also be immobilised for a sufficient length of time, and this is considerably longer than the period necessary for the union of a fracture.

3. **Extension of Disease.**—Extension of disease occurs most frequently in tuberculosis, in which the optimum moment for arthrodesis must be selected. This moment is *when the limit of bone destruction has been reached*, as shown in the radiograph by areas of density, sclerosis or bone regeneration. Though these criteria are fairly reliable, other factors must be considered, such as abscess, or sinus formation and, most *important*, the general condition of the patient

Premature operation may lead to the actual spread of disease as a result of the surgical removal of as yet invisible barriers of resistance. A knowledge of the common paths of extension of disease may be utilised when performing an extra-articular

operation, so that the bone graft may be placed in a "safe area." It is even possible to operate on a joint in the presence of pus or sinuses by the use of the appropriate approach and "siting" of the graft.

4 **Operations Based on Faultily Conceived Mechanical Principles.**—Having decided to perform an arthrodesis, the surgeon should consider:

(*a*) The anatomical approach to the joint

(*b*) The mechanical principles which affect and influence the joint during the period when fusion is taking place and afterwards

Considerable attention has been paid to the surgical approaches to all joints. These cannot be accused of dwelling in anatomical twilight The hip joint can claim as many as five approaches and the elbow almost as many Each has, however, been advocated by its exponents either as a method of ease of approach or because of the advantage of drainage in acute arthritis. There can be little doubt, therefore, that ease of anatomical access has led to the neglect of this second factor mentioned above, namely, the mechanical or architectural principles which should be employed in arthrodesis.

In a short review of the present methods of arthrodesis in practice it will be seen that little attention is paid to these principles. In the two largest joints in the body, **the shoulder** and **the hip,** arthrodesis, supplemented by an extra-articular graft, is usually performed by the easiest route Thus arthrodesis of the shoulder has been performed from above for many years with portions of the acromion and clavicle used as grafts, and attached to the upper and outer surface of the humerus. This technique ignores the important fact that the shoulder joint tends to adduct through gravity, and even the smallest amount of adduction will tend to make the humerus leave the grafts, with resulting failure of fusion.

The method of fusion usually attempted **in the hip joint** is by means of a graft extending from the ilium to the great trochanter, with or without an intra-articular erasion This is also an easy anatomical approach, and here again adduction, the strongest muscle pull, may dislodge either end of the graft with resulting

failure. Trumble[1] has attempted to avoid these faults in his ingenious ischiofemoral arthrodesis, an operation on which the ischiofemoral arthrodesis of the writer is based, which will be described later. Trumble's operation has, however, some disadvantages. Furthermore, in the hip there must be contact of bone between the head of the femur and the acetabulum, as otherwise the strain on the iliac graft will be too great.

In the knee joint, separation of the denuded surfaces is the most common displacement, and not even the most careful application of external fixation will always prevent this.

In the following pages a series of operations are described in which an attempt is made to put arthrodesis on a sounder architectural basis. It is not claimed that by these methods arthrodesis will be successful in every case, nor is it suggested that these are necessarily applicable to every patient, but it is hoped, however, that by using such mechanical principles a much higher percentage of fusions will be recorded.

REFERENCE

[1] Trumble, H. C., *British Journal of Surgery*, xxiv, 96, April 1937.

CHAPTER III

ARCHITECTURAL PRINCIPLES

THE importance of the careful coaptation of opposing joint surfaces has already been stressed, and also the necessity for using a bone graft in every arthrodesis. The placing of this graft in the most favourable site is of decisive importance. It is not enough that the graft must have an adequate bed at each end and be firmly secured. It must not be subjected to muscle pull, wasting of muscles or gravity. Even after the joint has apparently fused, too great a strain must be withheld or the graft may fracture.

Certain elementary principles must be observed, and the first of these is that, where possible **the graft should be placed with its long axis in compression rather than in tension.** Such materials as steel wires, struts or wooden beams can withstand as great a tensile force as compression strain, and are unlikely to fracture at any point in their long span. It is at each point of attachment that tension will operate, and these are the weak points both in architecture and in arthrodesis

A simple analogy is that of a lamp hanging from a wall by a bracket and supported by a stay (Fig. 1). If the stay is placed above the bracket it is subjected to a *tensile force* in its long axis, and while the stay is unlikely to fracture in its long axis, it may give way at either end. If placed underneath the bracket it is subjected to a *compression strain*, so that each end is constantly being made more secure (Fig. 2). It is obvious that the underlying support is therefore the stronger of the two.

Not as complete an analogy, but at the same time apposite, is that of a fused iliofemoral arthrodesis of the hip and a flying buttress of a church or cathedral. Fig 3 shows a picture of a flying buttress of Norwich Cathedral This travels from the ground past the triforium to the clerestory, and is actually in compression and architecturally sound There is an outward thrust from the

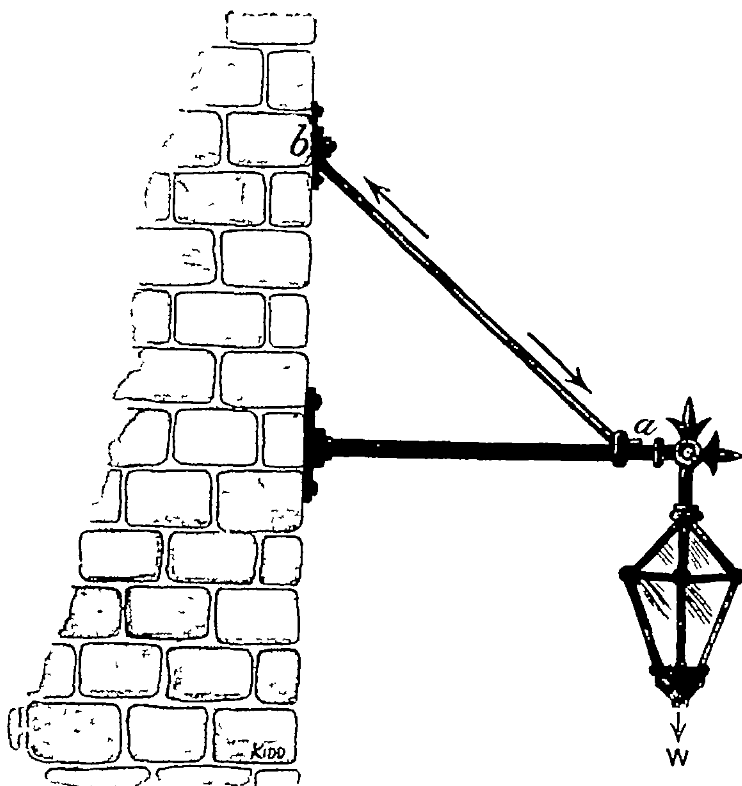


FIG 1

Lamp hanging from a wall by a bracket and supported by an overlying stay The stay is in tension, and there is a tendency to disruption at points A and B

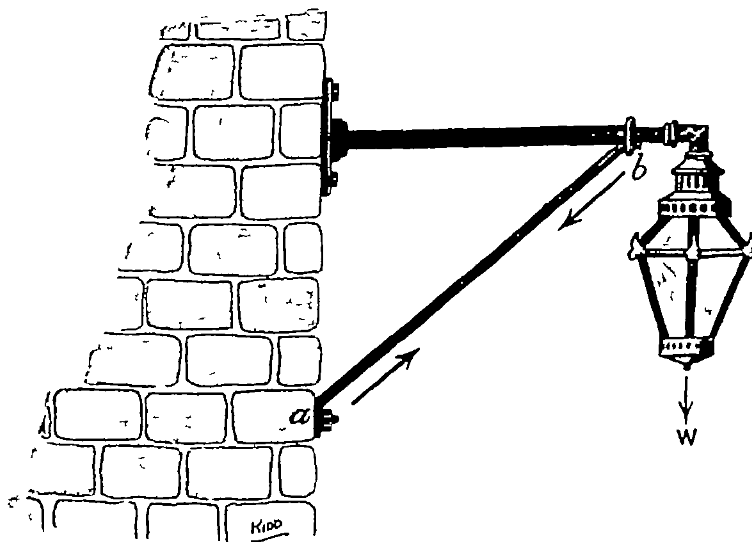


FIG 2

Lamp hanging from a wall by a bracket and supported by an underlying stay The stay is in compression, consequently points A and B are tending to become more secure

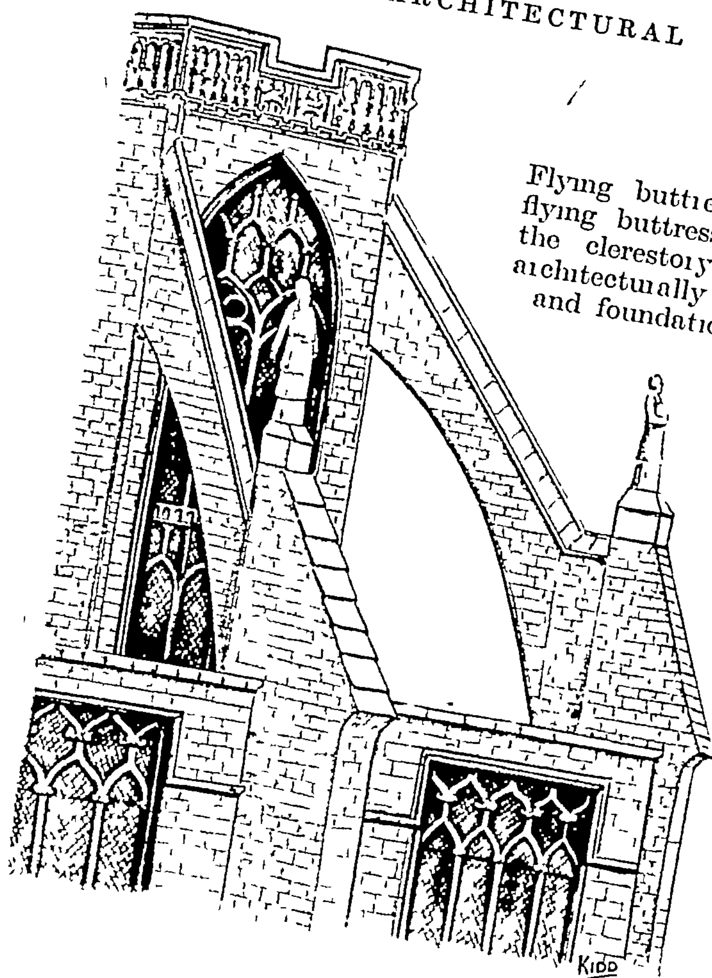


FIG 3
Flying buttress of Norwich Cathedral The flying buttress travels from the triforium to the clerestory, and is in compression and architecturally sound, provided that the roof and foundations of the building are sound.

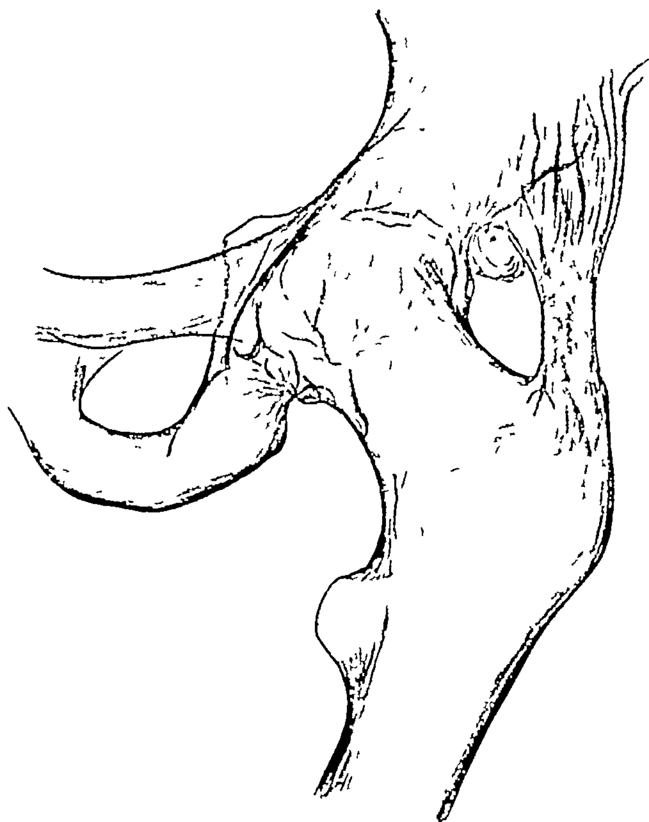


FIG 4
Reproduction of X-ray of extra-articular iliofemoral arthrodesis of the hip, similar to a flying buttress and consequently architecturally sound once it has fused, provided that there is continuity of bone between the head of the femur and the acetabulum

side wall of the clerestory at the upper end and an upward thrust from the ground past the *triforium* This is architecturally similar to a soundly fused iliofemoral arthrodesis (Fig. 4) Here there is an outward thrust from the pelvis and an upward thrust from the ground Should, however, the roof sag, the flying buttress would be subjected to tension at its upper end (Fig 5). Should the ground give way it would be subjected to tension at its lower

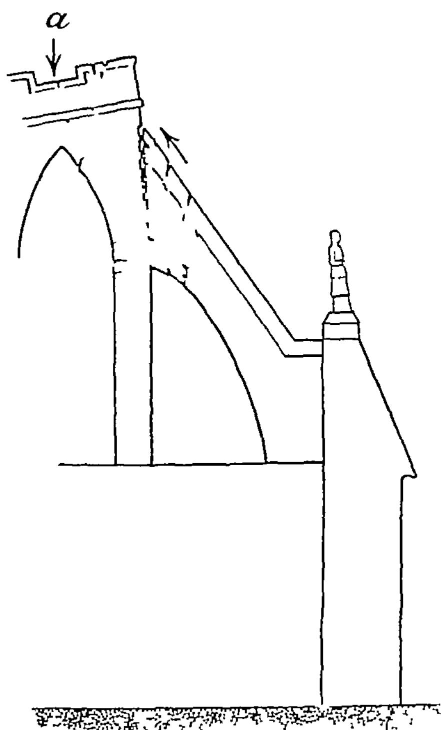


FIG 5

Flying buttress in tension at upper end, due to roof giving way

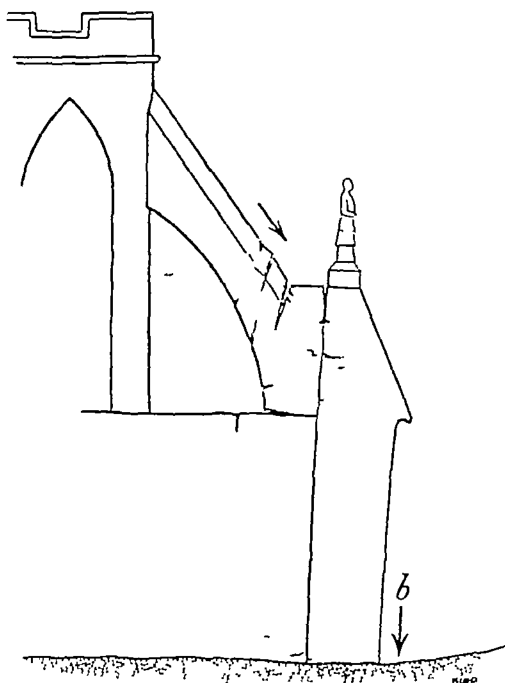


FIG 6

Flying buttress in tension at lower end, due to foundations of the building giving way

end (Fig 6) The roof sagging is similar to disease occurring between the acetabulum and the head of the femur, causing a space to appear and too great a tension strain to be placed on the graft. The ground giving way is similar to the adductor pull, which invariably takes place to some extent in the hip joint during the period of immobilisation When an arthrodesis is supplemented by an extra-articular graft, however, for some months afterwards the weakest point of the graft will be at the centre, until the graft is revascularised and replaced by bone from the host. It is

possible, therefore, that a graft may actually fracture in its long axis if too great a tension strain is placed on it (Fig. 7). Fig. 8 shows Gothic arches of Norwich Cathedral. These are in compression and are very strong. Architecturally similar, though not so beautiful, is an arthrodesis achieved by means of ischio-



Fig 7

Reproduction of X-ray of unsuccessful iliofemoral arthrodesis of the hip Disease has continued between the head of the femur and the acetabulum, resulting in too great a strain on the iliofemoral graft which has fractured in its long axis

femoral grafting (Fig. 9). There is a compression strain in the long axis of the graft, and as a result there has been tremendous hypertrophy.

To repeat, therefore, the first principle to be borne in mind is that **an extra-articular graft should, where possible, be placed in compression rather than tension.** It is not possible to fulfil this principle in all joints, nor is an architect able to fulfil it constantly in all buildings. When, however, an architect has to submit a beam or strut to tension, he makes it of a material sufficiently strong to withstand tension. Although surgeons have in the past used metal for fixation, in arthrodesis to-day one

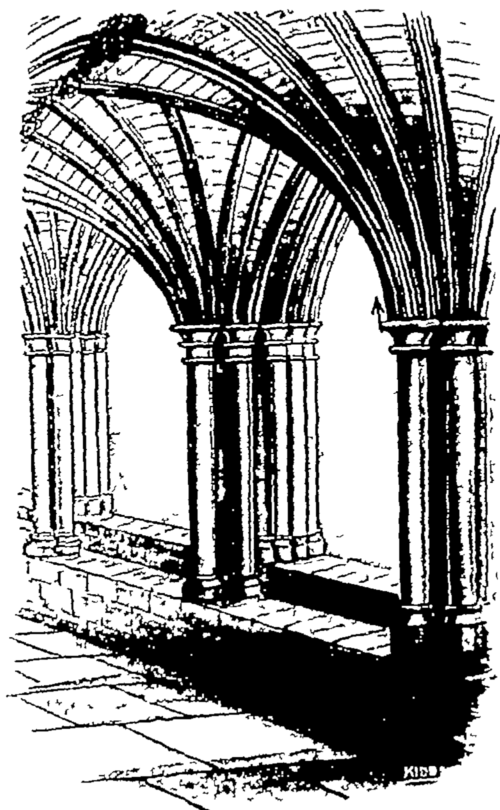


Fig 8
Gothic arches of Norwich Cathedral in compression and very strong

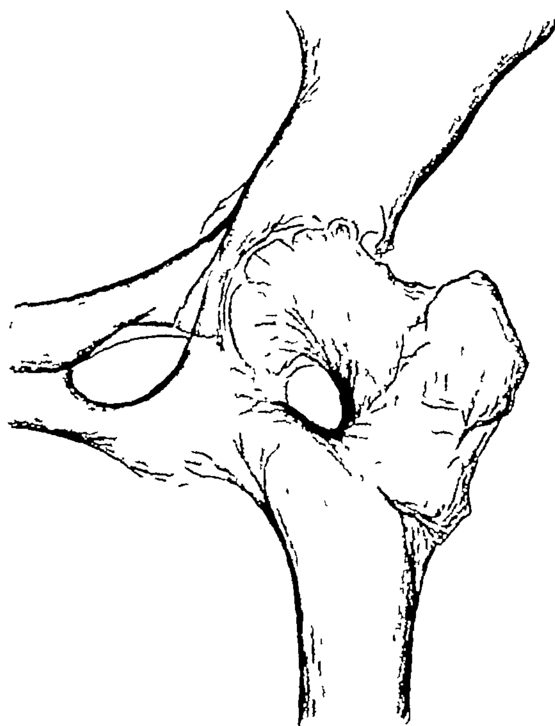


Fig 9
Reproduction of X-ray of arthrodesis of the hip by means of a graft between the ischium and the great trochanter Operation four years ago The graft is in compression and has hypertrophied enormously

material only is regarded as satisfactory,[1] the bone graft, various strengths of this living material may be selected, as, example, the crest of the tibia as opposed to the medial surf Where the principle of compression cannot be applied, **adequ protection of the graft** may be obtained either by burying deeply or by using more than one graft.

The second principle to be borne in mind is that **the brea of the graft should be placed in the position of maximum str**

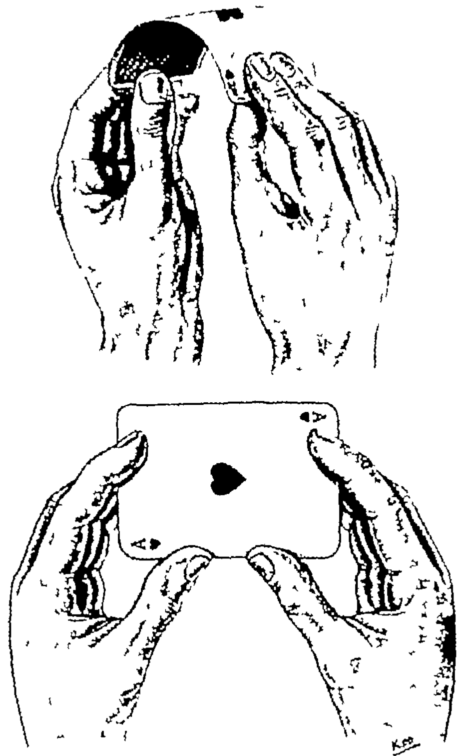


FIG 10

The breadth of a graft should be placed in the position of greatest stress A playing card, which can be bent easily by curving it on the edge, has much *greater resistance to being curved on the flat*

The breaking point of a graft varies, depending on whethe breadth or its depth is subjected to stress. A playing card be bent quite easily by curving it on the edge, that is, appr mating the ends of the same surface to each other.[2] Consider force is necessary, however, before it can be curved on the (Fig 10) This will be easily seen if a pack of cards is used. while a pack of cards can be bent slightly, it cannot be cu on the flat by ordinary human effort. *In fusion of the wrist j* where the flexion strain is the predominant one, this prin

[1] An exception to this is arthrodesis by a Smith-Petersen nail, as described by (see Chap XIII)

[2] "The Shape and Physical Qualities of the Minoan Shield," by Prof A E H Love,]

should be utilised. Therefore the graft is placed with its cancellous side towards the radial or ulnar aspect It should also be used in the elbow and knee joints, where two grafts are used with their cancellous surfaces facing each other, their breadth therefore being placed in the position of flexion and extension stress.

The third principle is that where possible **a joint should be locked by two grafts crossing each other in the shape of the letter X.** This principle is best applied in arthrodesis of the knee and elbow The knee joint can be subjected to a wide variety of strains, valgus, varus, recurvatum. flexion or separation of the bone ends

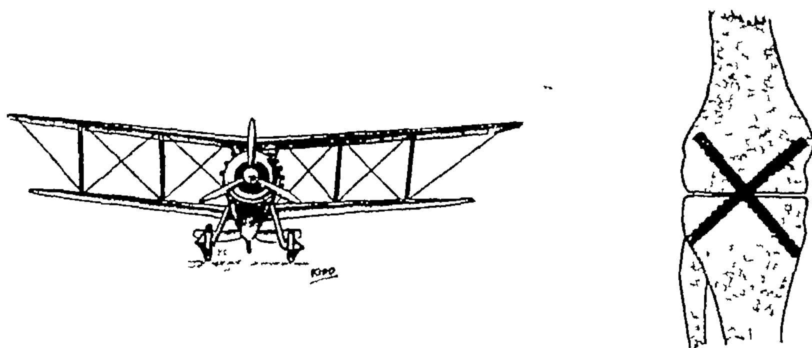


FIG 11

Comparison between the cross-bracing of a biplane and cross-grafting in arthrodesis of the knee Both cross-bracing and cross-grafting restrict movement to a minimum

in the long axis of the femur or tibia X grafts lock this joint and prevent it coming apart Valgus will cause the bone in the opposite angle of the X to be compressed against the graft, and varus the reverse

A simple analogy is that of the cross-bracing of the wings of a biplane, which although subjected to terrific strain are securely held[1] (Fig 11).

The fourth principle, already referred to, is the **adequate protection of the graft,** and is used in the ankle joint and the spine. In the ankle joint a central bone graft must be used, and the graft is adequately protected by burying it deeply so that it is surrounded by bone on all of its surfaces As the spine must be fused from behind, the graft must be in tension, as the flexion strain is the predominant one Here multiple bone grafts

[1] It is also seen in the protective casing of soda water siphons, the soda water being of the home-made variety

are used, as these throw out most bone. The laminæ are raised up laterally and left attached, and the spinous processes are sutured back in place over the grafts. The grafts are thus supported in front and behind and also at the sides. A sandwich is formed of which the bread is the spinous processes behind and the denuded laminæ in front, while the jam consists of the multiple bone grafts.

In this chapter, therefore, the four architectural principles advocated for arthrodesis are:—

1. **The graft should be placed with its long axis in compression rather than in tension.**
2. **The breadth of the graft should be placed in the position of maximum stress.**
3. **A joint should be locked by two grafts crossing each other in the shape of the letter X.**
4. **There should be adequate protection of the graft.**

CHAPTER IV

BONE GRAFTS FROM THE TIBIA

IN a classical passage from Cunningham's "Manual of Practical Anatomy" there appears :—

"The galea aponeurotica is only loosely connected to the pericranium by the layer of loose areolar tissue and can easily be torn from the pericranium, a circumstance taken advantage of by the Indians who scalped their defeated foes"

A modern counterpart of the Indian is the orthopædic surgeon who unscrupulously takes advantage of the fact that the medial surface of the tibia is subcutaneous throughout its entire length, and uses it as his source of supply of bone grafts. No other bone is so popular, the fibula, the crest of the ilium, and the ribs (in spite of Biblical precedent) coming a long way behind. The tibia, far from resenting such onslaughts upon it, seems to appreciate this attention by regenerating to even greater size and strength than before.[1]

Various strengths, sizes and shapes of grafts can be selected, using an electric saw, and it is essential for the success of the arthrodesis of certain joints to cut the grafts to particular shapes, and to cut them strong enough. The types of grafts advocated are as follows :—

1. **A straight graft from the medial surface of the tibia,** not including the crest, cut to the exact size required, as for arthrodesis of the elbow. This is the type of graft most commonly used for un-united fractures Its length is carefully defined beforehand. The periosteum may or may not be left attached according to individual preference, and the twin wheels of the saw may be used if desired. The writer's personal preference is to remove all periosteum, use one wheel and ignore the saline drip. The argument that the heat of the saw kills the osteoblasts if this is

[1] I have recently seen an injured workman who had suffered more than twelve operations of bone grafting, both tibiæ being used. Each bone had hypertrophied enormously

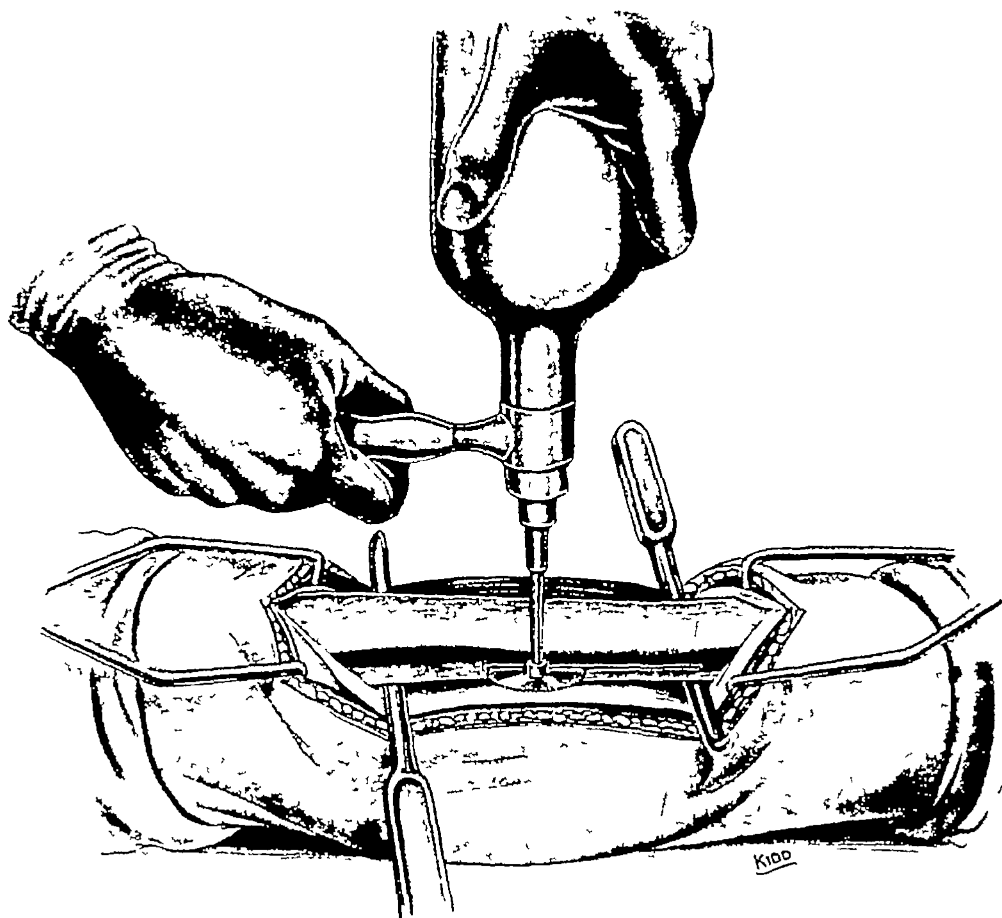


FIG 12

Cutting a tibial graft for ischiofemoral arthrodesis The periosteum is completely removed from the tibia, and two bone elevators are passed underneath The graft is cut from the posterior and lateral surfaces

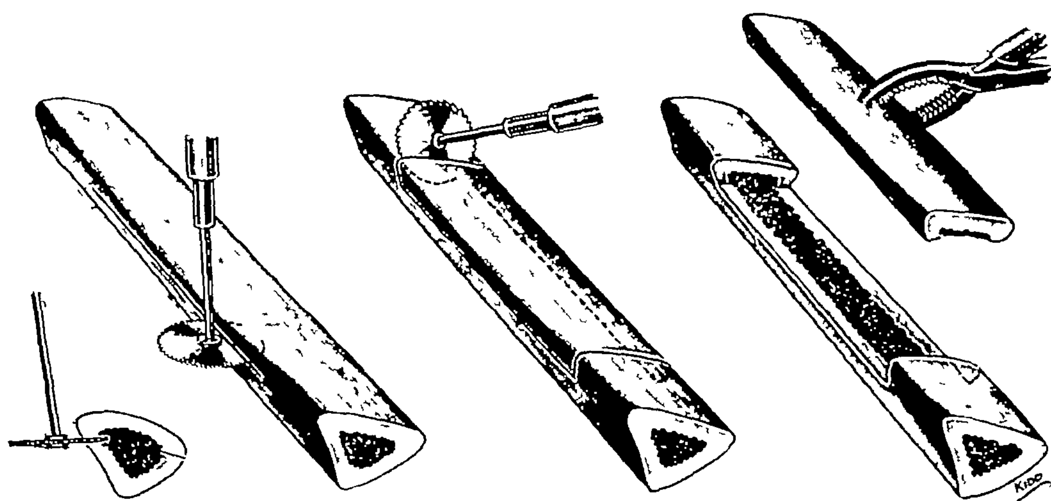


FIG 13

Diagrammatic representation of a tibial graft for ischiofemoral arthrodesis

not used has been proved fallacious by experience The graft must be completely cut through by the saw before removal, and it is the assistant's responsibility to see that it does not fly from its bed

2. **A massive graft consisting of the entire medial surface of the tibia,** and including both the crest and the medial margin,

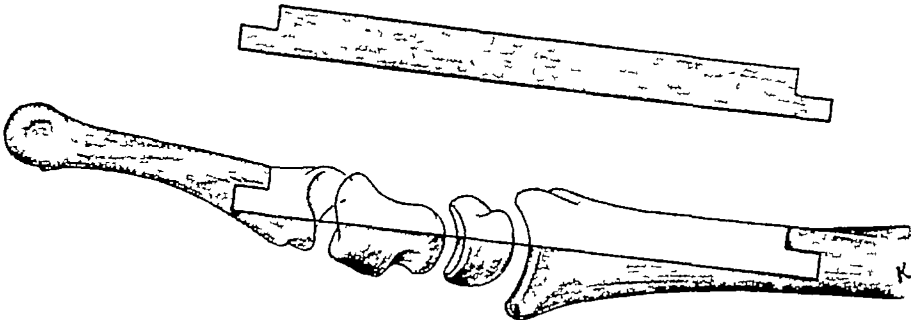


FIG 14
Bail graft for arthrodesis of the wrist

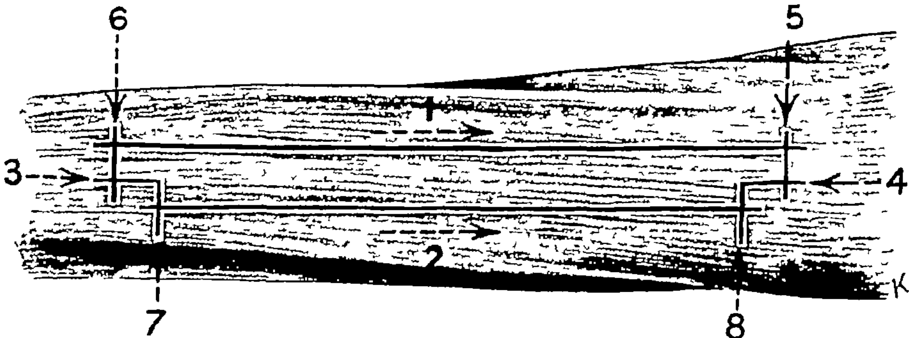


FIG 15
Cutting a bail graft with the electric saw The cuts are made *according to the numbers and travel in the direction of the arrows* so that the graft is cut at the expense of the unused tibia, and is at no time encroached upon

as for ischiofemoral arthrodesis (Fig 12) A graft 4 to 5 in. in length is usually sufficient (Fig 13) An incision 7 in long is made over the *middle of the skin of the* subcutaneous surface of the tibia The periosteum is removed from the entire tibia throughout the length of the incision Two bone elevators are passed subperiosteally beneath the posterior surface of the tibia, and slid towards the distal ends of the wound. This gives an excellent exposure A bone graft 5 in long is cut to include both the anterior crest and medial margins of the tibia. It is therefore cut through the lateral and posterior surfaces, and these are

joined across the medial surface at each end. The periosteum is carefully sewn over the remainder of the tibia. It will be found that this is quite easily done, as the breadth of the tibia has been decreased. At least one half of the diameter of the tibia should

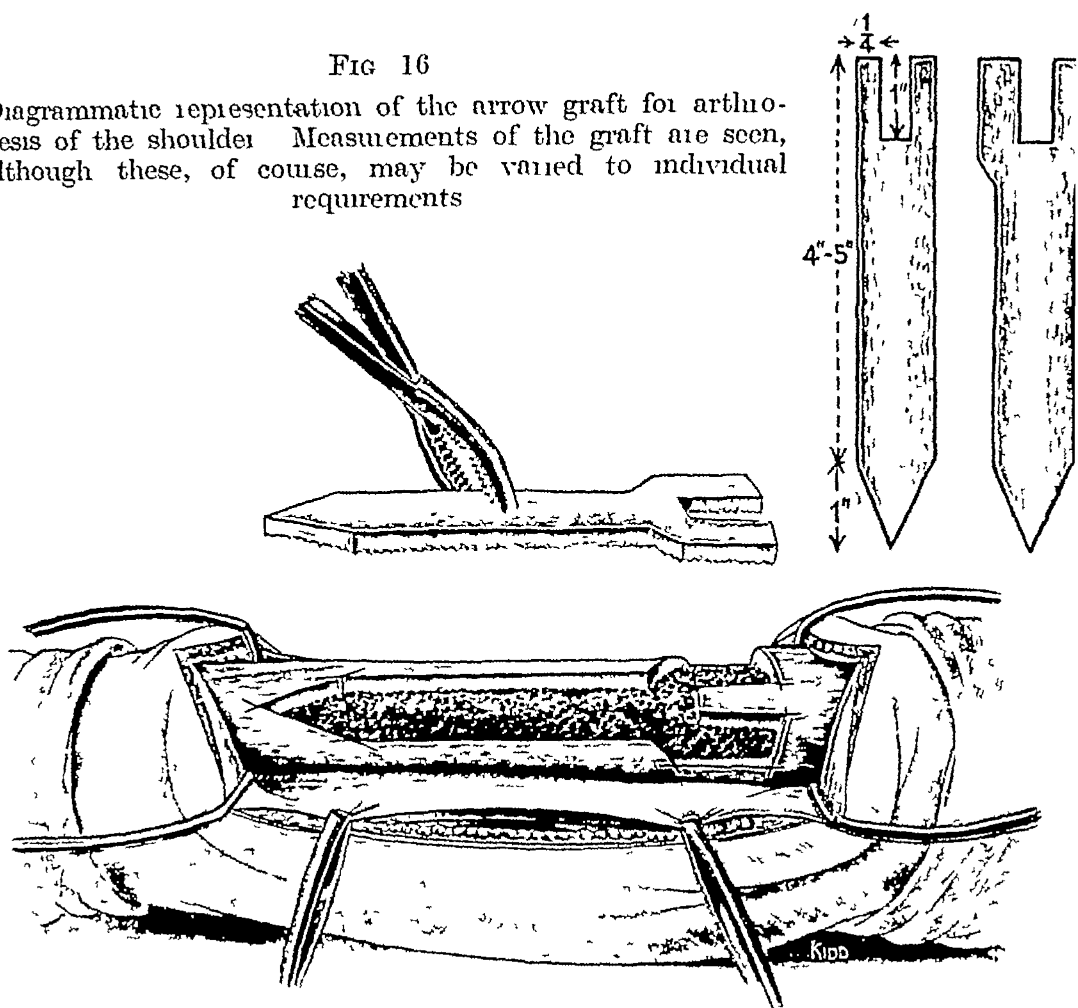


Fig 16

Diagrammatic representation of the arrow graft for arthrodesis of the shoulder Measurements of the graft are seen, although these, of course, may be varied to individual requirements

Fig 17

The arrow graft being taken from the tibia The cuts are always made away from the graft at *the expense of the tibia that is not being used* The notch of the arrow should be taken from the upper end, and the lateral and posterior surfaces may be encroached upon

be left, and as the periosteal tube has been restored, the tibia shortly regenerates again as strong as or stronger than before. The skin is sutured, and it may be considered necessary to encase the limb in plaster of Paris.

3. **The elongated bail graft with a step at each end** (Fig. 14) as for arthrodesis of the wrist. This graft is cut from the medial surface of the tibia. The graft should be ½ in. wide. It is about 4 in. long, and a step ¼ in. by ¼ in. is cut at each end. This can

be cut quite easily at the expense of the bone which is not going to be used (Fig. 15) The angle in the step must not be encroached upon.

4 **The single bar graft,** as for arthrodesis of the ankle This is similar to Fig 14, except that there is a step at one end only

5 **Twin grafts cut from the upper third of the tibia** and including part of the crest, as for arthrodesis of the knee These grafts are

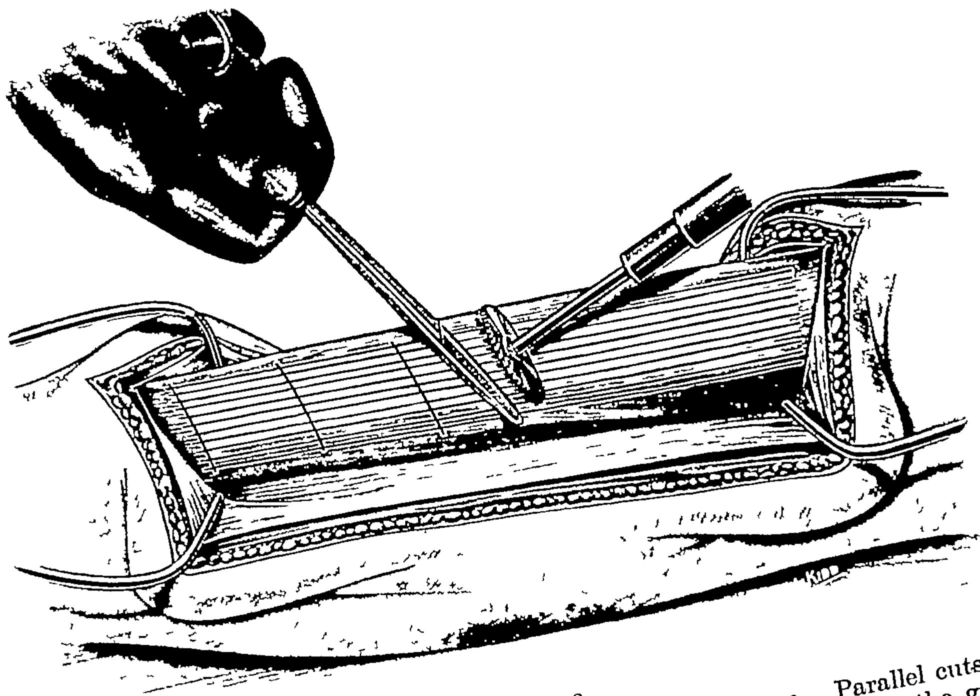


Fig 18

Method of cutting multiple grafts for arthrodesis of the spine Parallel cuts are made in the tibia from $\frac{1}{12}$ to $\frac{1}{4}$ in apart The assistant must hold the grafts down, as otherwise they may fly out while the transverse cuts are being made

5 in. long and $\frac{1}{2}$ in in breadth. They are cut from 2 in below the knee joint. One is cut from the anterior surface and the other from the medial surface. They are separated by an incision straight down the crest of the tibia Each graft, therefore, includes a part of the crest (see p 49, Fig. 69)

6 **The arrow graft,** as for arthrodesis of the shoulder This is 6 in long, pointed at one end and with two wide limbs at the other The point is 1 in. long, and the graft should be as wide as the anterior surface of the tibia will permit (Fig. 16). The

limbs are cut from the upper end of the tibia, and should be $\frac{1}{4}$ in. wide and 1 in. long. They are cut at the expense of the unused tibia, and it is vitally important that the limbs of the arrow should not be weakened by any cross-cuts (Fig. 17)

7. **Chip grafts,** as for fusion of the spine (Fig. 18). These are cut from the medial surface of the tibia Parallel lines $\frac{1}{12}$ in. apart may be cut for a length of 6, 7 or 8 in. Transverse cuts are made through these at intervals of 1 to $1\frac{1}{2}$ in. Care must be taken to see that the grafts do not fly out from the tibia prematurely while the transverse cuts are being made

CHAPTER V

ARTHRODESIS OF THE HIP

THE largest joint in the body, the hip joint, is a common site of arthritis calling for surgical interference. This comprises various reconstruction operations—*formal arthroplasty, subtrochanteric osteotomy, acetabuloplasty* and **arthrodesis.** A discussion on the merits of these operations would be out of place here They all have their indications. Undoubtedly in some patients a successful arthroplasty may be performed, but in the great majority it is excluded either by the nature of the disease or the age of the patient. In well-established tuberculous disease, especially in the adult, bony ankylosis is the end-point of treatment, and this, with a few exceptions, can rarely be obtained except by arthrodesis

Arthrodesis of the hip is a formidable operation and presents technical difficulties. The usual procedures advocated are, in **tuberculous arthritis :** (1) *an extra- or para-articular iliofemoral arthrodesis,* when either an iliac or tibial graft is used travelling from the ilium to the great trochanter; (2) *a combined intra- and para-articular arthrodesis,* in which the joint is opened, the disease erased and a similar graft used.

For the success of the extra- or para-articular iliofemoral arthrodesis one essential must be realised **the limit of bone destruction must be reached.** This means that there must be bony contact between the head of the femur and the acetabulum If disease progresses there, so that an area of caseation is substituted for this firm contact, too great a strain will be thrown on the graft, and it will fracture or become disrupted at either end. Also, progressive disease may have involved the ilium or the great trochanter, and thus prohibit the insertion of a graft This moment, *i.e.*, when bone destruction has ceased, may never occur, or it may occur so late that an iliofemoral arthrodesis is difficult or impossible, for example, in a pseudarthrosis when a patho-

logical dislocation has occurred Occasionally an abscess may be opened at an early stage, when the operation ceases to be extra-articular.

The combined operation is also a formidable procedure. Children do not tolerate it easily. There is frequently post-operative shock, and complete extirpation of the disease may be difficult or even impossible. Here, again, **the limit of bone destruction should have been reached,** otherwise the surgeon may excise invisible barriers of resistance and cause further spread of disease. There may be technical difficulties in producing contact between the head of the femur and the ilium if a considerable amount of bone has to be excised. Post-operative sinuses are not unusual.

Osteo-arthritis and Infective Arthritis.—In osteo-arthritis the patients are elderly, and the bone, whether hypertrophic or atrophic, does not tend to fuse easily. An extra-articular operation alone is usually insufficient to produce fusion, and in any event does not correct deformity. The combined intra- and extra-articular operation is again a formidable procedure, and the forcible dislocation of the hip at operation undoubtedly causes shock It must therefore be withheld from a certain group of patients, the frail and elderly, or at any rate those above a certain age, depending on the technical skill of the individual surgeon. A luxury procedure should carry a negligible mortality !

All these operations have one common disadvantage, that while fusion is taking place the hip joint is subjected to the predominant force of adduction, and that any graft from the ilium to the great trochanter may thus lose contact at either end. Even in plaster the hip joint adducts, wasting takes place, and unless absolute immobilisation is preserved muscle-spasm may occur. It is possible to cater for this adduction by burying the graft deeply in the great trochanter, but the movement that may occur may make the union insecure.

Ischiofemoral arthrodesis is the obvious alternative method of fusing the hip. This procedure was first envisaged by Calvé [1] as the most logical type of arthrodesis, but it was left to Trumble to make the first practical suggestion of surmounting the inherent difficulties of the operation. Trumble's operation has, however, a difficult anatomical approach, and the sciatic nerve is apt to be

an obstacle. Continuity of bone between the head of the femur and the acetabulum is desirable for successful fusion, and this may not always be available

The operation devised by the writer and here described consists of a subtrochanteric osteotomy through which the ischium immediately below the acetabulum is incised by a wide osteotome, and a space made in it to receive a flat, massive, tibial bone graft This is embedded deeply in the ischium, and its outer part remains between the fragments of the osteotomy.

This operation presents certain advantages :—

1 **It is a simple procedure and does not cause shock.**

2 **It is extra-articular.** Disease extending downwards into the ischium is a rare complication.

3 **The graft is in compression instead of tension.** The adductor strain prevalent in the hip tends to make the attachments of the graft constantly more secure.

4. **It can be performed in elderly patients with osteo-arthritis where an iliofemoral arthrodesis is out of the question.** It is of special value here because of the weight transference Even if fusion does not take place, a subtrochanteric osteotomy has been performed which relieves pain. In two osteo-arthritic patients, in the earlier cases of the series reported, here fusion did not occur, but the patients had no complaints

5. **By allowing the hip joint to adduct the "cavity is collapsed."** Just as in the spine the prematurely performed Albee operation holds the spine in extension, and by this may be the cause of preserving activity of disease because it does not permit collapse of the vertebral bodies and consequent anterior contact, so the hip joint treated in abduction may prevent the diseased surfaces coalescing. The number of tuberculous hips that one has seen fused in abduction without surgical interference are few—in adduction, numerous

6 **In unreduced congenital dislocation or subluxation of the hip** in middle-aged patients with arthritic changes and pain, an ischiofemoral arthrodesis is probably the operation of choice Complete relief from pain may be

prefeıred to the partial ıelief obtained by an osteotomy of eıtheı the Lorenz or Shanz type. An ılıofemoral arthrodesıs ıs dıfficult or ımpossıble ın thıs condıtıon, because of the dıfficulty of fusıng the femur to the dorsum ılıı

7 **The operatıon can be performed at an earlıer stage ın tuberculous dısease,** as one ıs short-cırcuıtıng the dısease and ısolatıng ıt. The cortıcal surface of the graft beıng turned uppermost acts as a barrier to the dısease whıle unıon ıs takıng place.

8 **In old pseudarthroses, wıth smoulderıng tuberculous disease,** ıt ıs ımpossıble to produce firm fusıon by any other means.

Operatıon.—The patıent lıes on hıs back wıth the affected hıp over the edge of the table, but not tılted ın any way. An X-ray

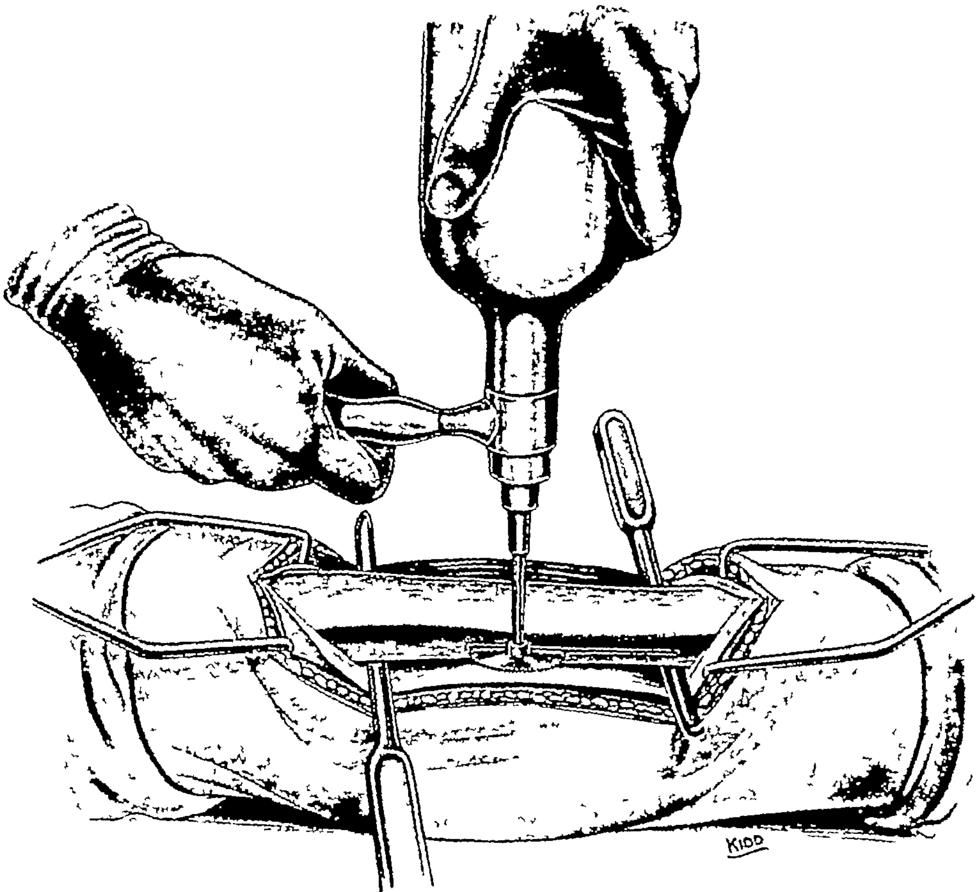


FIG 19

Ischıofemoral arthrodesıs Cuttıng the tıbıal graft The perıosteum ıs completely removed from the tıbıa, and two bone elevators are passed underneath the tıbıa The graft ıs cut from the posterıor and lateral surfaces

cassette is placed under the hip, and the operation sites are covered with towels. These sites are usually the opposite tibia, the upper 6 in of the femur, including the anterior and lateral aspects, and the groin from the pubis to the anterior superior iliac spine. A Michel clip is placed on the skin in the groin at a point midway between the junction of the upper two-thirds and lower third of the distance between the anterior spine and the symphysis A radiograph is taken. While this is being developed the tibial graft is cut (Figs 19 and 21) An incision 7 in. long is made over the front of the tibia. The periosteum is stripped from the medial surface of the tibia and also from the posterior and



FIG 20

Radiograph of patient taken in the theatre The Michel clips are on the skin

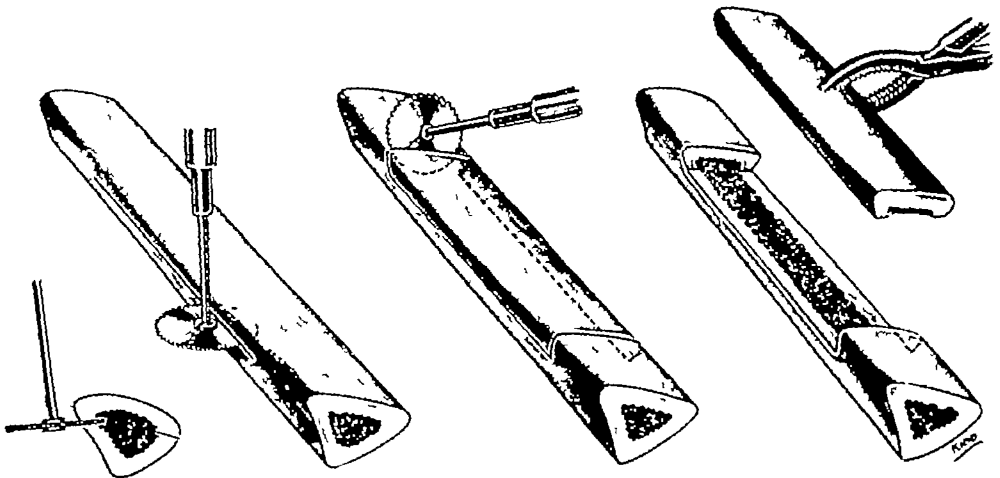


FIG 21

Ischiofemoral arthrodesis Diagrammatic representation of shape of tibial graft

lateral surfaces, and two elevators are passed underneath the tibia and then slid to the opposite ends of the wound. This presses the skin and muscles well down away from the tibia, so that a flat

graft can be cut which includes both the anterior crest and the medial margin The graft is 5 in long and is flat and very strong

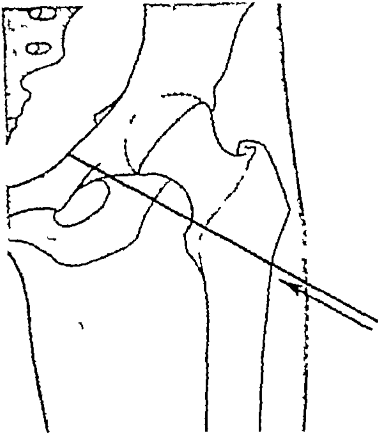


FIG 22

Ischiofemoral arthrodesis Subtrochanteric osteotomy being performed The osteotome is aimed at the clip on the patient's skin

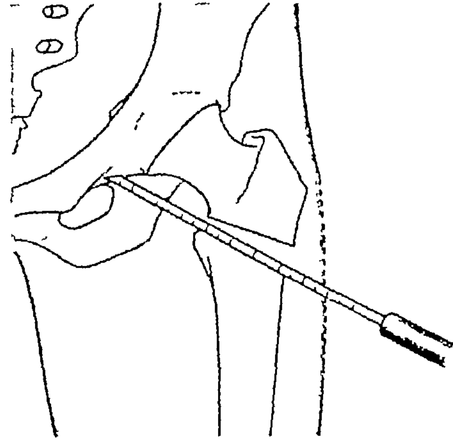


FIG 23

The graduated chisel has been passed into the ischium just below the acetabulum for a distance of 1 in A radiograph is taken

(Fig. 21) Furthermore, an additional advantage lies in taking these tibial borders, as the breadth of the tibia being decreased the edges of the periosteum can be sewn together easily over the tibia, helping bone regeneration

After the wound is closed the radiograph is inspected, and it will be seen that the clip is usually situated over the upper margin of the obturator foramen, just below the acetabulum This is the point to aim for, and if the first clip is incorrectly placed, adjustments can be made and another clip placed on the skin The table is then levered up to its fullest height The reason for this is that the graft is most easily cut when the table is low, but the patient must lie



FIG 24

Radiograph taken in the theatre Osteotomy has been performed, and the osteotome is in the ischium

flat on his back so that a true radiograph can be taken, and the osteotomy can be most easily performed when the table is high.

A 4-in incision is now made over the great trochanter, which is exposed A bone elevator is passed over the anterior surface

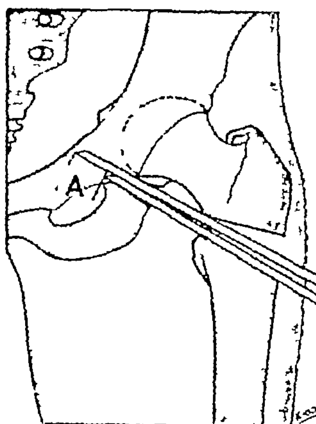


FIG 25

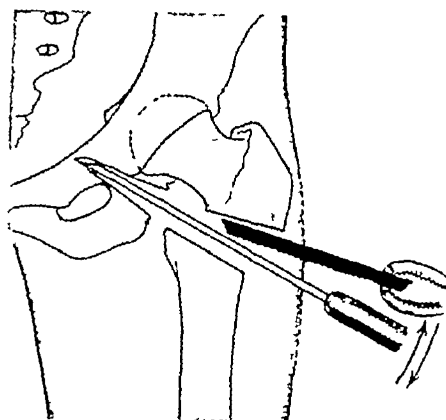


FIG 26

FIG 25—A second chisel precisely the same size as the first is introduced above it and in the same line, though inclining slightly It will be noted from the previous radiograph exactly how far it can be inserted, as the chisels are of equal length

FIG 26—The second chisel has been removed and is replaced by the graft

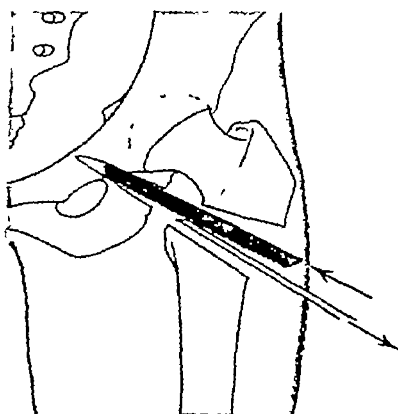


FIG 27

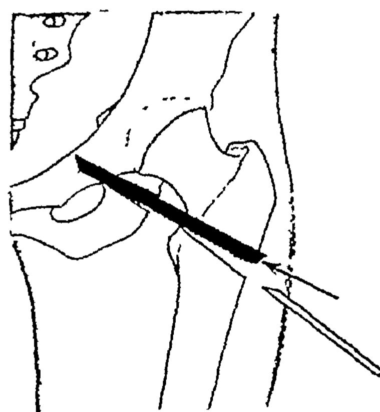


FIG 28

FIG 27—The graft is inserted into the aperture in the ischium, and the first chisel is being removed

FIG 28—The graft is punched well home into the ischium

of the femur above the small trochanter, and this also serves as a landmark. A subtrochanteric osteotomy is performed, and the osteotome should be aimed in the direction of the clip on the skin. and in the coronal plane of the body (Fig. 22). An osteotome $1\frac{1}{2}$ in. wide and 6 in. long should be used, and it should be calibrated. The osteotomy should be performed cleanly, and should not be concluded by fracturing the inner edge of the femur After it has been completed the osteotome should be pushed onwards

gently in the same line until bony resistance is again felt. It is surprising how easily this can be done in practice. Contact usually occurs after 1½ in, and the osteotome is then driven in for a further inch A second radiograph is now taken (Figs. 23 and 24). The assistant exerts traction on the limb, and a second osteotome precisely the same size as the first is now inserted above the first and parallel to it. It will actually be slightly converging The second radiograph will show how much farther the osteotome can

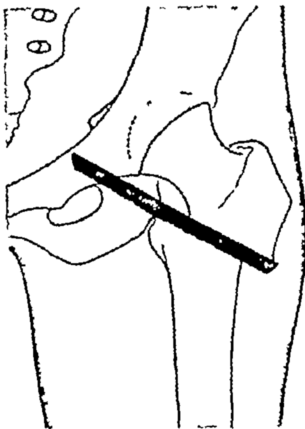


FIG 29

The graft is *in situ* and the femur has been manipulated so that there is contact between the small trochanter and the ischium below the graft



FIG 30

Radiograph taken in the theatre The graft is in position It can be pushed a little farther if desired

travel before it enters the pelvis, and as the osteotomes are equal in length the second one can be hammered in the precise amount farther than the first (Fig. 25). The second osteotome is then removed, and the graft substituted for it with its cancellous surface downwards (Fig. 26). The graft should fit into the aperture made by the second osteotome, and after it has been hammered in for ½ in or so the first osteotome is also removed (Fig 27). The graft is then punched in until resistance is felt, and then punched a little harder so that it is firmly impacted in the ischium (Fig. 28). The limb is then abducted so that the lower fragment abuts against the ischium below the graft (Figs. 29 and 30). The wound is closed in layers in the usual way, and a complete plaster spica is applied.

REFERENCE

[1] Ref to Calvé quoted by Galland, M, in "Proceedings of VI^{eme} Congres de l'Association International de Thalasso Thérapie" Berck, 1931

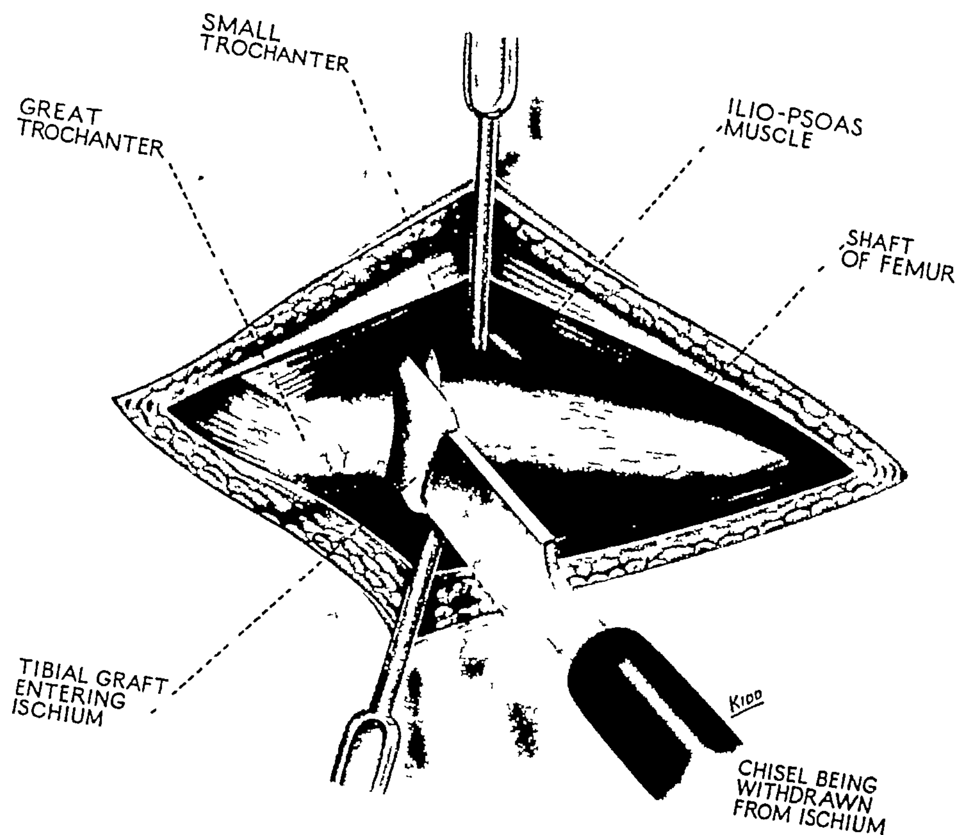


Fig 31

Ischiofemoral arthrodesis The graft is fitting smoothly over the second chisel, which is about to be withdrawn The graft is not quite home Its end should lie in the osteotomy site

SUMMARY OF RESULTS OF ISCHIOFEMORAL ARTHRODESIS

Case No	Age	Disease	Length of History	Operation	Present Condition
1, V H	17	Tuberculosis of hip	8 yr	Feb 20, 1936	Fused
2, P R	15	Ditto	1 yr 8 mth	July 15, 1937	Fused
3, E D	32	Ditto	6 yr	Aug 8, 1937	Fused
4, V C	14	Ditto	3 yr	Oct 2, 1937	Fused
5, C S	63	Osteo-arthritis	—	May 20, 1938	Fused
6, M R	57	Ditto	—	June 1, 1938	Fused
6, G L	17	Tuberculosis of hip	6 yr	June 20, 1938	Fused
8, E W	56	Osteo-arthritis secondary to congenital dislocation of hip	—	Nov 11, 1938	Not fused, but no complaints
9, F P	56	Osteo-arthritis	—	Nov 16, 1938	Fused
10, D T	22	Tuberculosis of hip	4 yr	Nov 20, 1938	Fused
11, D M	48	Infective arthritis	—	Dec 2, 1938	Fused
12, J J	54	Osteo-arthritis	—	Dec 11, 1938	Fused
13, A D	28	Infective arthritis	2 yr	Dec 18, 1938	Fused
14, A B	36	Tuberculosis of hip	24 yr intermittent	April 21, 1939	Fused Fibrous union between trochanter and shaft No complaints
15, N C	15	Ditto	9 yr	June 29, 1939	Fused
16, A S	62	Osteo-arthritis	—	July 21, 1939	Not fused, but no complaints
17, I C	28	Osteo-arthritis secondary to congenital dislocation of hip	—	July 31, 1939	Fused
18, E R	62	Osteo-arthritis	—	Aug 20, 1939	Fused
19, J L	16	Tuberculosis of hip	10 yr	Aug 22, 1939	Fused
20, R B	9	Ditto	2 yr	Sept 7, 1939	Fused Disease still active
21, M C	10	Ditto	1 yr 8 mth	Sept 21, 1939	Fused
22, D B	9	Ditto	4 yr	Oct 5, 1939	Not fused Disease involving graft
23, B B	18	Ditto	11 yr	Oct 25, 1939	Not fused Disease involving graft
24, F B	16	Ditto	4 yr	Oct 27, 1939	Fused Two operations
25, M M	41	Ditto	34 yr intermittent	Nov 8, 1939	Fused
26, M G	58	Osteo-arthritis	—	Nov 24, 1939	Fused
27, S G	16	Tuberculosis of hip	10 yr	Dec 4, 1939	Fused
28, C N	58	Osteo-arthritis	—	April 10, 1940	Fused
29, P B	9	Tuberculosis of hip	5 yr	April 18, 1940	Fused Three operations
30, R S	61	Osteo-arthritis secondary to congenital dislocation of hip	—	April 21, 1940	Fused
31, F B	10	Tuberculosis of hip	7 yr	April 25, 1940	Fused
32, J B	11	Ditto	4 yr	April 27, 1940	Fused
33, T C	19	Infective arthritis	—	May 10, 1940	Fused Two operations
34, P M	17	Osteo-arthritis secondary to congenital dislocation of hip	—	May 17, 1940	Fused
35, N J	58	Infective arthritis	—	June 5, 1940	Fused

One patient, aged 58, with osteo-arthritis, died eight days after operation from a pulmonary embolus confirmed by post-mortem examination

RADIOGRAPHS FOR CHAPTER V

ARTHRODESIS OF THE HIP

OSTEO-ARTHRITIS



Fig 32

Osteo-aithiitis of the hip in a fat woman aged 60 Aithiodesis two years ago Fused





OSTEO-ARTHRITIS

Fig 33

Osteo-arthiitis of the hip in a man aged 61 Fused.

Fig 34

Osteo-aithritis of the hip in a man aged 58 Fused Note new bone apparently in obturatoi foramen



INFECTIVE ARTHRITIS

FIG 35

Infective arthritis of the hip in a woman aged 36 Operation four years ago Graft almost completely absorbed



FIG 36



FIG. 37

CONGENITAL DISLOCATION OF THE HIP

FIG 36 —Unreduced congenital dislocation of the hip in a boy aged 18 The graft has been inserted into the ilium Firmly fused

FIG 37 —Congenital subluxation of the hip in a woman aged 28 with arthritic changes and pain Firmly fused Graft taken from the femur Note new bone at inner end of graft Union slow between graft and distal fragment of the femur

TUBERCULOSIS OF THE HIP



FIG 38

Tuberculosis of the hip in a boy aged 16 Iliofemoral fusion attempted three years before Progressive disease and fracture of iliac graft



FIG 39

Same patient as Fig 38 One year after ischiofemoral arthrodesis Firmly fused



FIG 40

Turberculosis of the hip in a boy aged 16 Ten years' conservative treatment Active disease present



FIG 41

Same patient as Fig 40 Ischiofemoral arthrodesis Firmly fused



FIG 42

Same patient as Fig 40 One year later Note absorption of graft and retrabeculation occurring in area of previous disease

TUBERCULOSIS OF THE HIP



FIG 43



FIG 44

FIG 43 —Tuberculosis of the hip in a boy aged 15 Ten years' history of conservative treatment

FIG 44 —Same patient as Fig 43 Two years after ischiofemoral arthrodesis Firmly fused Osteotomy performed because of too much abduction



FIG 45



FIG 46

FIG 45 —Tuberculosis of the hip in a boy aged 10 Five years' history of conservative treatment Failed ischiofemoral arthrodesis due to involvement of graft by disease

FIG 46 —Tuberculosis of the hip in a boy aged 9 Fused Three operations necessary In the first operation the graft was not inserted far enough into the ischium In the second the graft was placed above the first graft in an area of disease instead of below and became involved by disease In the third the graft was placed well into the ischium below the first graft and has now obviously fused well These errors in technique should be easily avoided

ILLUSTRATING SHORT-CIRCUITING OF THE DISEASE INSTEAD OF ENCIRCLEMENT

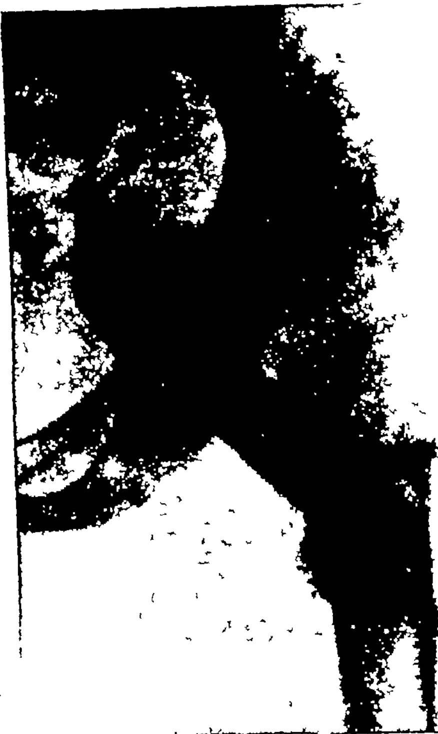


FIG 47



FIG 48

FIG 47 —Tubeiculosis of the hip in a boy aged 12 Active disease but firmly fused Note new bone at upper end of graft

FIG 48 —Same patient as Fig 47 Lateral view showing fusion at lowei end of graft



FIG 49

(*Mr W Rowley Bristow's patient*)

Tuberculosis of the hip in a man aged 42 Pus struck with first incision and it was difficult to avoid the diseased area Note apparent attacks on graft by disease Now firmly fused, particularly at the lowei surface The cortex of the graft, therefore, appears to act as a barrier against the spread of disease

ILLUSTRATING TREATMENT OF PSEUDARTHROSES



FIG 50



FIG 51

FIG 50 —Tuberculosis of the hip in a girl aged 17 Ten years' history of unstable hip with smouldering disease

FIG 51 —Same patient as Fig 50 Two years after arthrodesis Fused Re-trabeculation occurring



FIG 52



FIG 53

FIG 52 —Tuberculosis of the hip in a man aged 41 Thirty-four years' history of intermittent disease Unstable hip with adduction shortening and sinuses

FIG 53 —Same patient as Fig 52 Firmly fused Sinuses healed one year later

ILLUSTRATING TREATMENT OF PSEUDARTHROSES



FIG 54



FIG 55

FIG 54—Tuberculosis of the hip in a boy aged 17 Six years' history of pseudarthrosis and smouldering disease

FIG 55—Same patient as Fig 54 Three years after arthrodesis Graft almost completely absorbed Note re-trabeculation



FIG 56

Tuberculosis of the hip in a woman aged 36 Twenty-four years' history of intermittent disease Operation during active stage Now fused Graft passed into the pubis Note new bone around it Union slow at osteotomy site

ILLUSTRATING ADDUCTION IN PLASTER



Fig 57



Fig 58

Fig 57 —Tuberculosis of the hip in a girl aged 12 Seven years' history Note abscess in ilium

Fig 58 —Same patient as Fig 57 Radiograph taken in the theatre Note distance between small trochanter and ischium



Fig 59



Fig 60

Fig 59 —Same patient as Fig 57 Five months later Adduction has taken place in plaster so that small trochanter is now in contact with ischium Firmly fused Note disappearance of abscess in ilium

Fig 60 —Contrast between last patient and iliofemoral arthrodesis where adduction has taken place causing fibrous union between the iliac graft and the great trochanter

ILLUSTRATING HYPERTROPHY OF GRAFT



FIG 61

Tuberculosis of the hip in a girl aged 15 Operation four years ago after twenty months of disease Note enormous hypertrophy of graft

CHAPTER VI

ARTHRODESIS OF THE KNEE

THE knee is most frequently approached by surgeons with a view to fusion, and because of the large bony surfaces in contact, a high percentage of successes have been recorded Operative interference is also justified by the fact that conservative treatment usually fails to produce a stable, weight-bearing limb, and the fibrous ankylosis resulting from tuberculosis almost invariably relapses. Fibrous union after an attempt at arthrodesis is not, however, unknown This may be due to *incomplete eradication of the disease, inadequate immobilisation* or *insufficient apposition of the bony ends.* The resistance of the body is capable of dealing with a certain amount of residual disease more successfully if fusion is obtained Immobilisation is rendered more complete by the use of bone grafts, and bone grafts placed in the optimum site may help to maintain the apposition of the bony ends

The knee joint is vulnerable to strain in any direction Factors which produce fibrous union are five, in the following order of frequency (Figs. 62-66) —

1 **Separation of the bone ends due to too much extension in the long axis of the limb This is by far the most frequent displacement**

2 **Genu recurvatum.** 3 **Too much flexion.**

4 and 5 **Varus and valgus**

The procedure herein described consists of the usual dissection and eradication of disease, removing the articular cartilage with a twin-bladed saw as advocated by Calvé and Galland (Fig 68), curetting out any tuberculous cavities and fixing the knee joint **by two grafts cut from the tibia which are crossed in the shape of the letter** X (Fig 67) The cancellous surfaces of the grafts are

placed either towards or away from each other, so that **the breadth of the graft is in the position of greatest stress,** namely, flexion and extension. A valgus strain will tend to place the bone in the

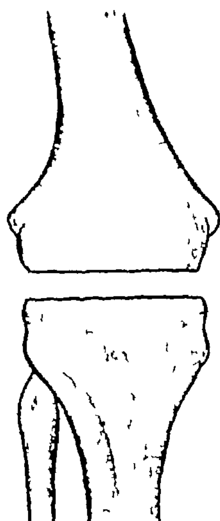


Fig 62
Separation

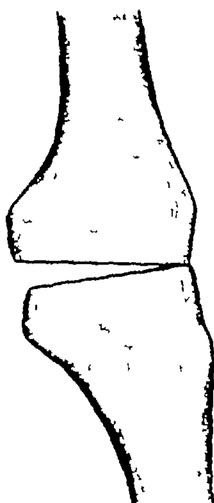


Fig 63
Recurvatum

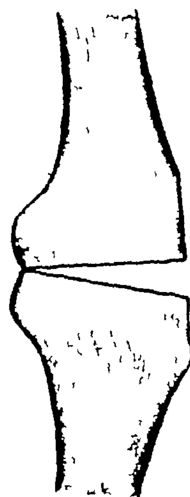


Fig 64
Flexion

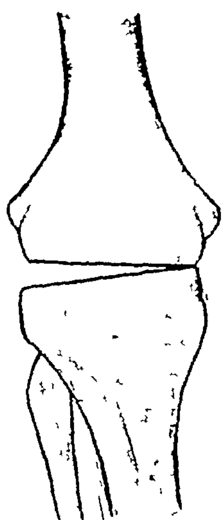


Fig 65
Varus

Figs 62-66
Common displacements preventing bony union in arthrodesis of the knee, in order of occurrence

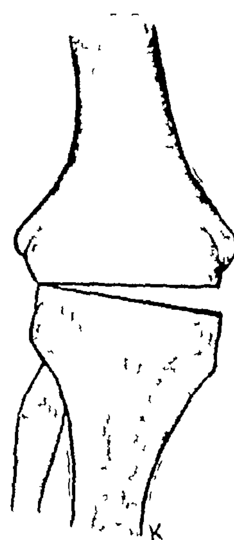


Fig 66
Valgus

lateral angles of the X in compression, and a varus strain the bone in the medial angles. **The X grafts will tend to lock the joint** and prevent the bony surfaces from coming apart.

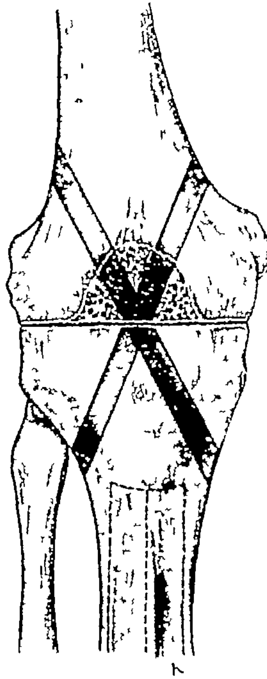


FIG 67

Diagrammatic representation of arthrodesis of the knee by X grafts

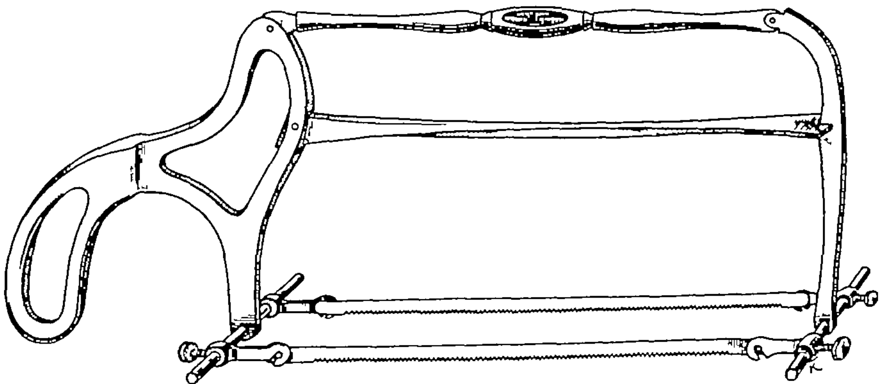


FIG 68

Twin-bladed saw, as made for the author by Messrs Down Bros On my return from Berck Plage in happier pre war days I attempted to draw Galland's saw from memory, and this was the result The chief difference is that Galland's tension screw is at the side instead of the top

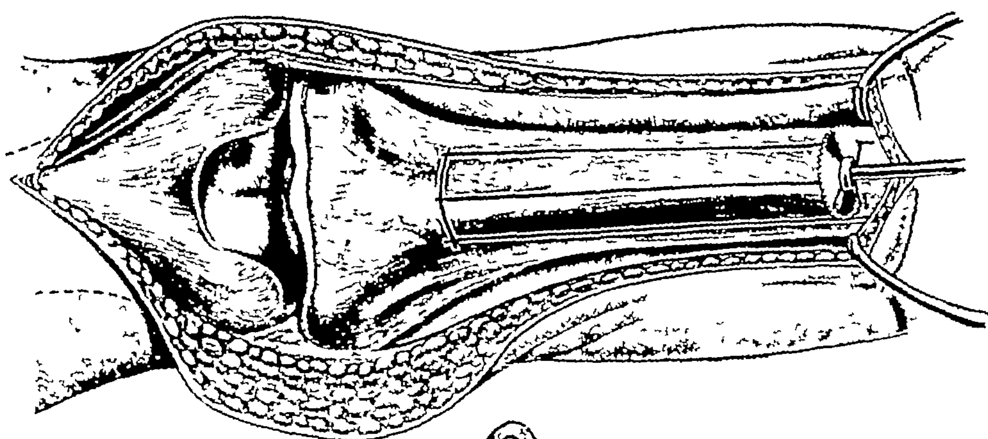


Fig 69
Grafts being cut from the tibia

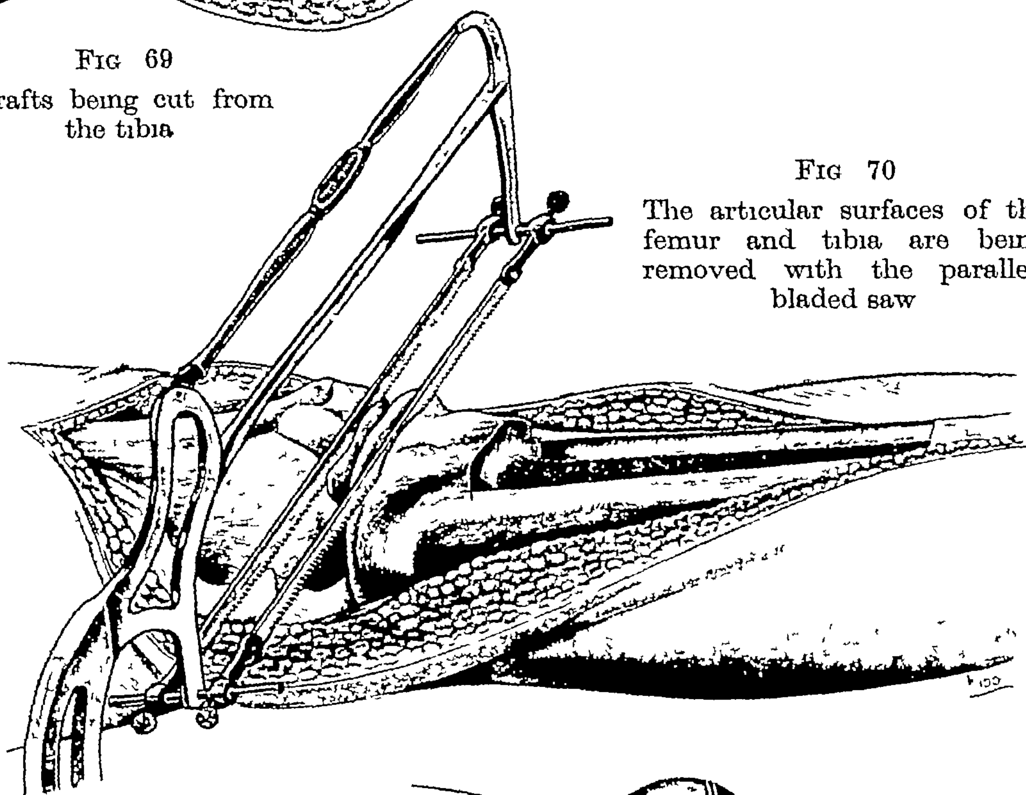


Fig 70
The articular surfaces of the femur and tibia are being removed with the parallel-bladed saw

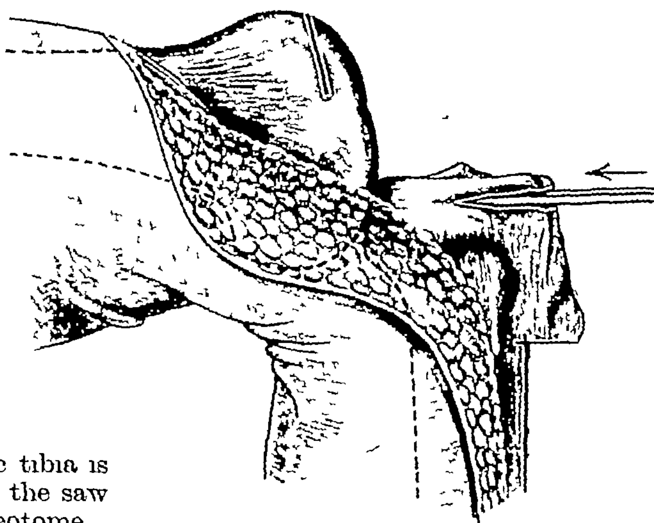


Fig 71
The knee is flexed to 90° The tibia is elevated against the femur and the saw cuts completed with a fine osteotome

Operation.—The operative details differ only a little from the usual arthrodesis of the knee A modified Kocher's incision is used This is prolonged down the crest of the tibia, and two bone grafts 5 in long are cut from the tibia (Fig. 69, p 49) They start 2 in below the knee joint, and they can first be cut as one graft to include part of the lateral surface and part of the posterior surface of the tibia They can then be divided along the crest The capsule is incised and the joint opened The suprapatellar pouch is dissected out and the patella is removed. All

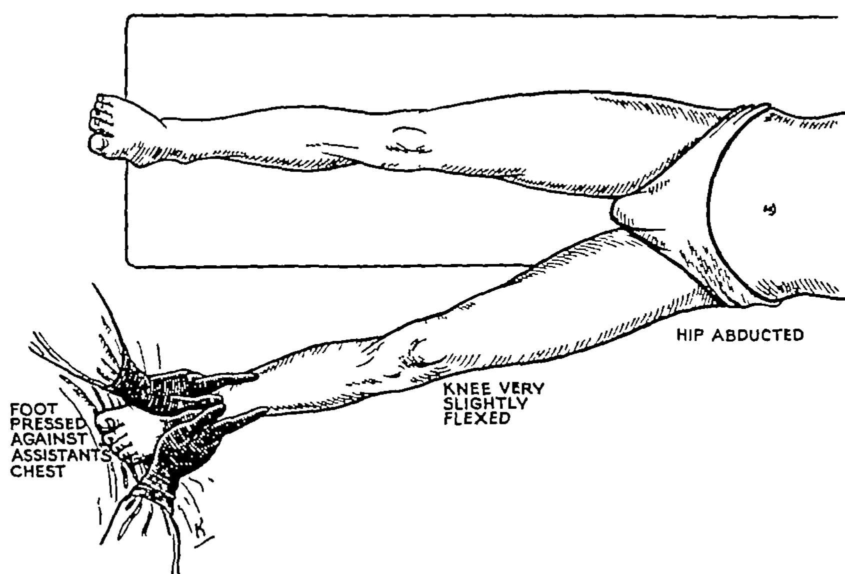


FIG 73

Method of holding the limb with interlocking hands so that the plaster can be applied after arthrodesis of the knee

diseased tissues are carefully excised. Two parallel cuts are now made in the tibia and femur with a twin-bladed saw (Fig 70). The advantages of the twin-bladed saw have been pointed out by Galland As long as the blades are parallel the cuts may be made in valgus, varus, recurvatum or flexion, and the parallel surfaces will still be in complete apposition The saw cuts are carried down for about 1 in , and the knee joint is then fully opened, the semilunar cartilages removed and the intercondylar fossa carefully dissected out The saw cuts are completed by a fine osteotome (Fig 71) Two chisels are introduced through the head of the tibia from the anteromedial and anterolateral aspects, passing upwards obliquely through the femur One of them may

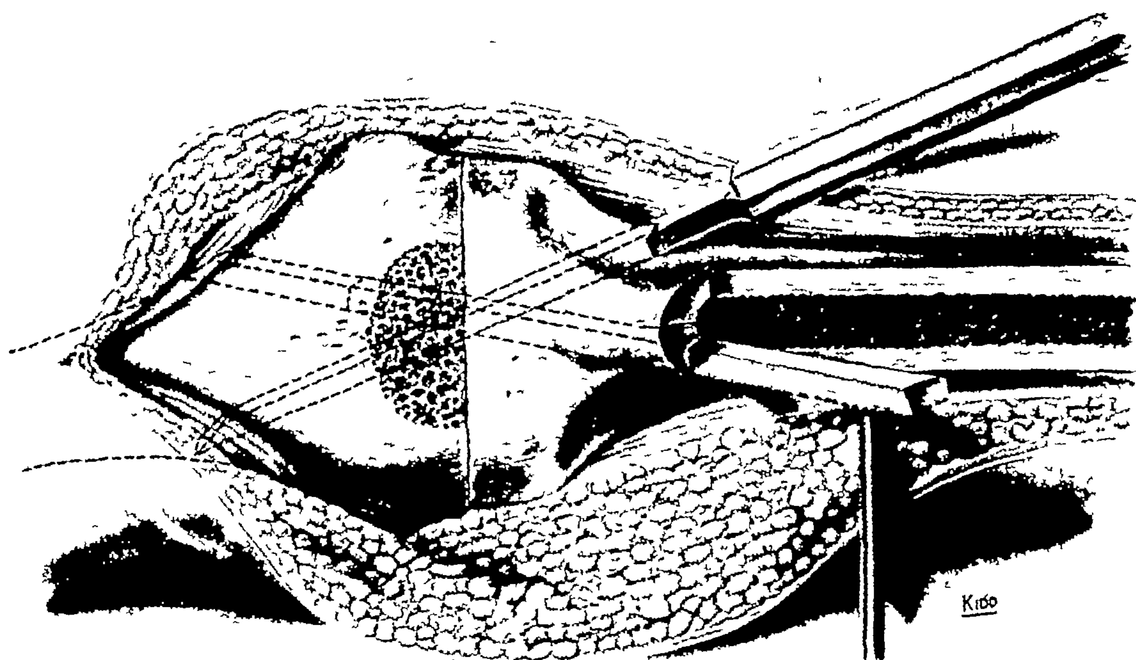


FIG 72

Arthrodesis of the knee One chisel has been replaced by a graft which is being driven home Its breadth is in the position of greatest stress

be introduced through the upper part of the bed in the tibia from which the graft has been taken The first is left *in situ* as the second is passed up, so that the second does not encounter it. The first chisel is removed and one graft is inserted in the gutter left by it, and punched up along the track, care being taken to see that no separation between the tibia and femur occurs, the second chisel remaining *in situ* until the first graft has been well buried (Fig 72) The second graft is then inserted into the bed made by the other chisel. The limb is put into plaster of Paris just below the Esmarch's bandage, and by abducting the hip an assistant can hold the limb at the ankle with interlocking hands and keep the knee steady, so that the plaster can be put on without the position of the limb being altered (Fig 73) The plaster is then increased to a complete hip spica and maintained until fusion has occurred.

RADIOGRAPHS FOR CHAPTER VI

ARTHRODESIS OF THE KNEE



FIG 74
Unstable knee in recurvatum due to infantile paralysis in a woman aged 54



FIG 75
Same patient as Fig 74 Arthrodesis by means of X grafts



FIG 76
Same patient as Fig 74 Lateral view



FIG 77
Tuberculosis of the knee in a woman aged 48 Arthrodesis by means of X grafts



FIG 78
Same patient as Fig 77 Lateral view





Fig 79

Tuberculosis of the knee in a woman aged 36 Arthrodesis by means of X grafts

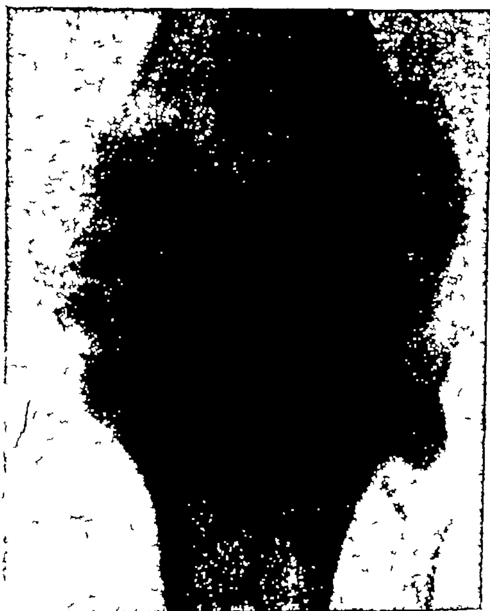


Fig 80

Old fender fracture in a man aged 44. Arthrodesis by means of X grafts



Fig 81

Same patient as Fig 80 Lateral view

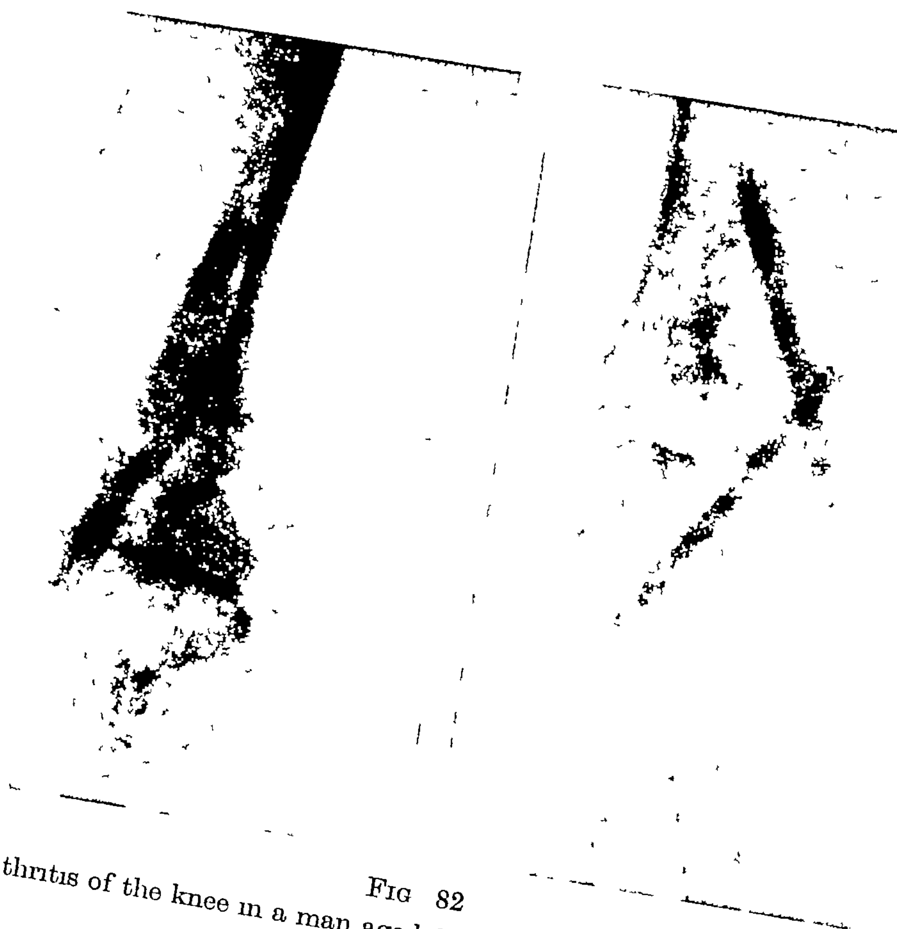


FIG 82

Osteo-arthritis of the knee in a man aged 64 Arthrodesis by means of X grafts

CHAPTER VII

ARTHRODESIS OF THE ANKLE

A FUSED ankle joint gives very good function, and if a successful fusion is at all feasible the result is greatly to be preferred to amputation. The indications for arthrodesis are similar to those for other joints, *healed tuberculosis, infective arthritis* and *osteo-arthritis.* The latter almost invariably follows a *malunited Pott's fracture*

Arthrodesis, while usually successful if it is being performed for osteo-arthritis, may be very difficult in the presence of tuberculosis. Even after a successful fusion the disease may recur by extension to the subastragaloid joints, usually along the track of the external lateral ligament

There are technical and mechanical obstacles in performing an arthrodesis of the ankle joint, viz ·—

(*a*) The tibiofibular mortise will become too large through removal of the articular cartilages and diseased areas, so that adequate apposition is rendered difficult

(*b*) Disease may involve the astragalus to such an extent that there may be insufficient bone to hold a graft, and care must be taken not to penetrate the subastragaloid joint

(*c*) The ankle joint, like the hip, is the end of a long lever, and bony fusion must be complete before unprotected weight-bearing is allowed

The architectural principles to be observed are chiefly ·—

1 **Adequate Protection of the Graft** —This is obtained by burying the graft deeply and leaving an anterior bridge of tibia so that the graft as it traverses the ankle joint is totally enclosed (Fig 83)

2. **Compression of the Graft.**—This is difficult to obtain, but a bail graft may be cut at the upper end a little too long for the tibial bed, and forced into the medulla of the tibia (Figs. 84 and 85)

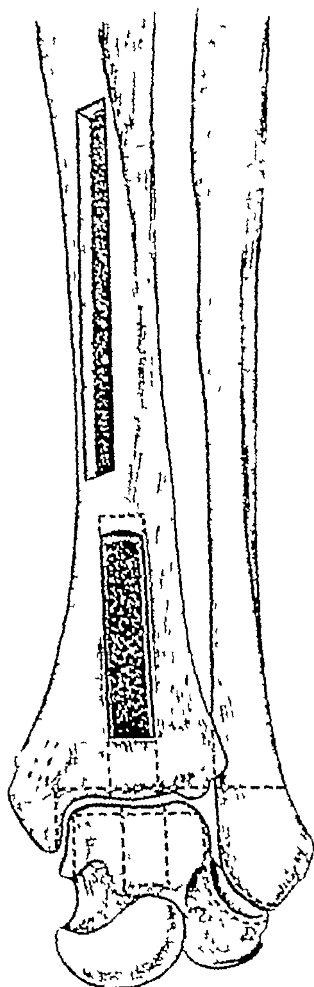


FIG 83

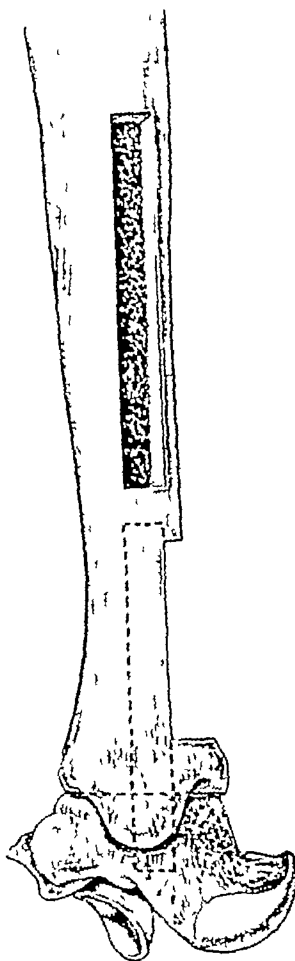


FIG 84

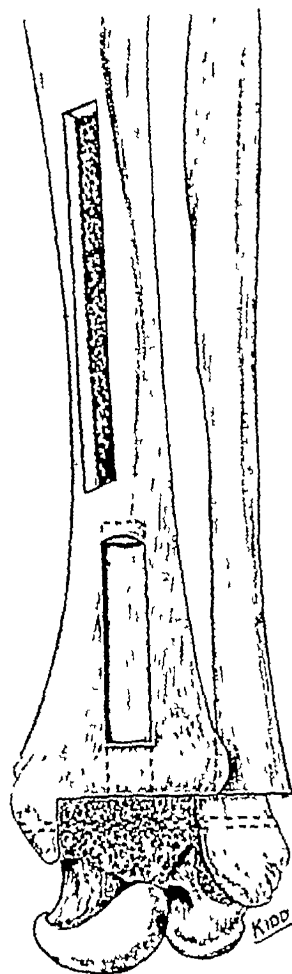


FIG 85

FIG 83 —Arthrodesis of the ankle Diagrammatic representation Line of erasion of cartilage and osteotomy of fibula Bail graft cut from the tibia to be inserted into the astragalus, leaving an anterior bridge of tibia Note that the internal malleolus and astragalus are cut square like a cube of sugar

FIG 84 —Lateral view Note the anterior bridge of tibia

FIG 85 —The bail graft is *in situ* overhung by tibia The transverse dotted lines indicate the passage of the drill or kangaroo tendon, lashing the malleoli and astragalus together

Furthermore, **adequate apposition of the bony surfaces** is obtained by cutting the upper and internal angle of the astragalus

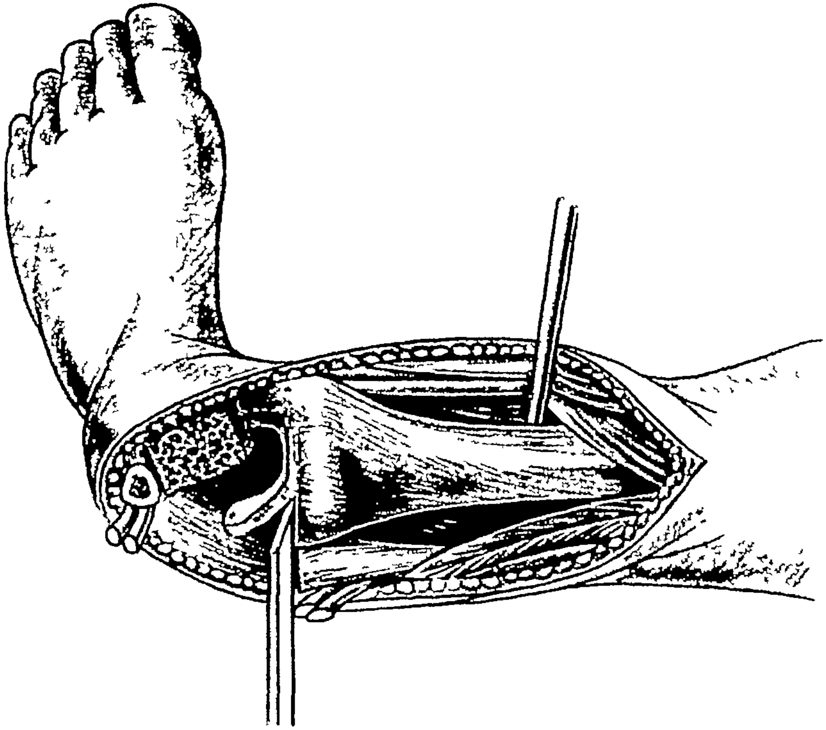


FIG 86

Arthrodesis of the ankle *An osteotomy of the fibula has been* performed and cartilage removed from the astragalus Cartilage is being removed from the lower surface of the tibia

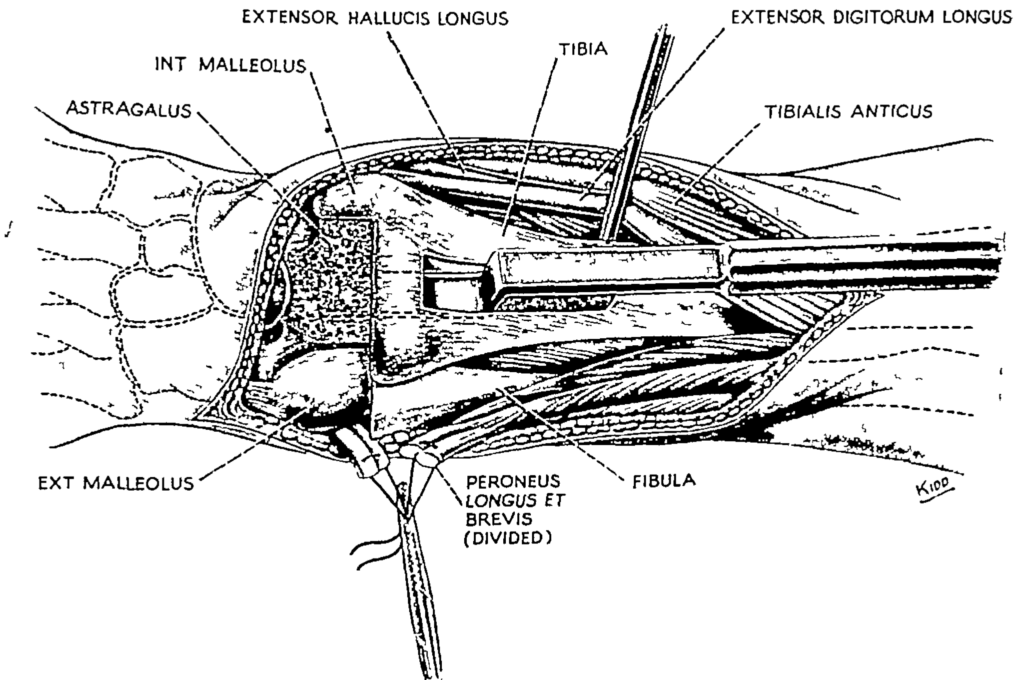


FIG 87

A special chisel being inserted into the astragalus An osteotomy of the fibula has been performed A graft will be taken from the tibia higher up

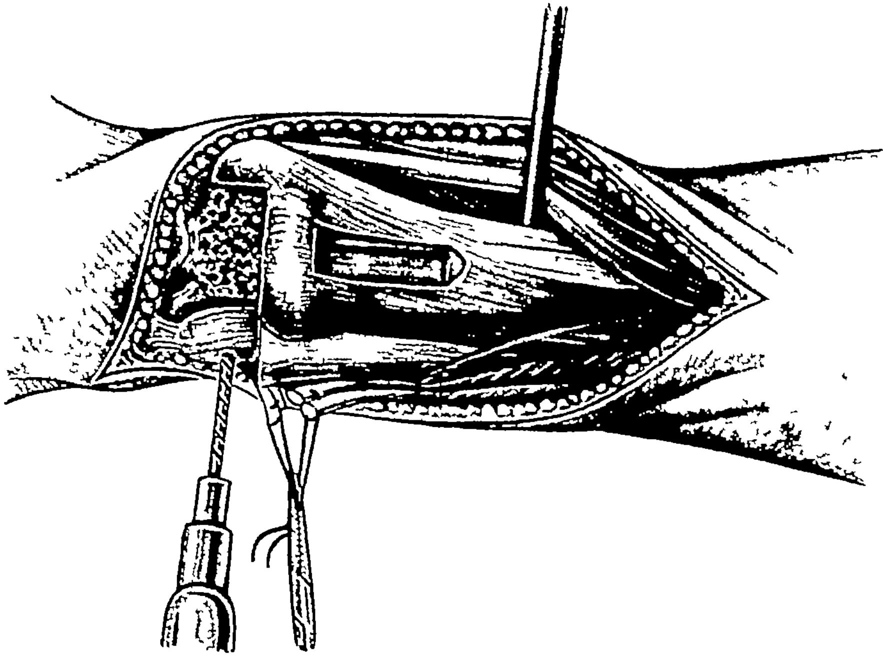


FIG 88

The graft in position A drill hole is being made through the malleoli and the astragalus

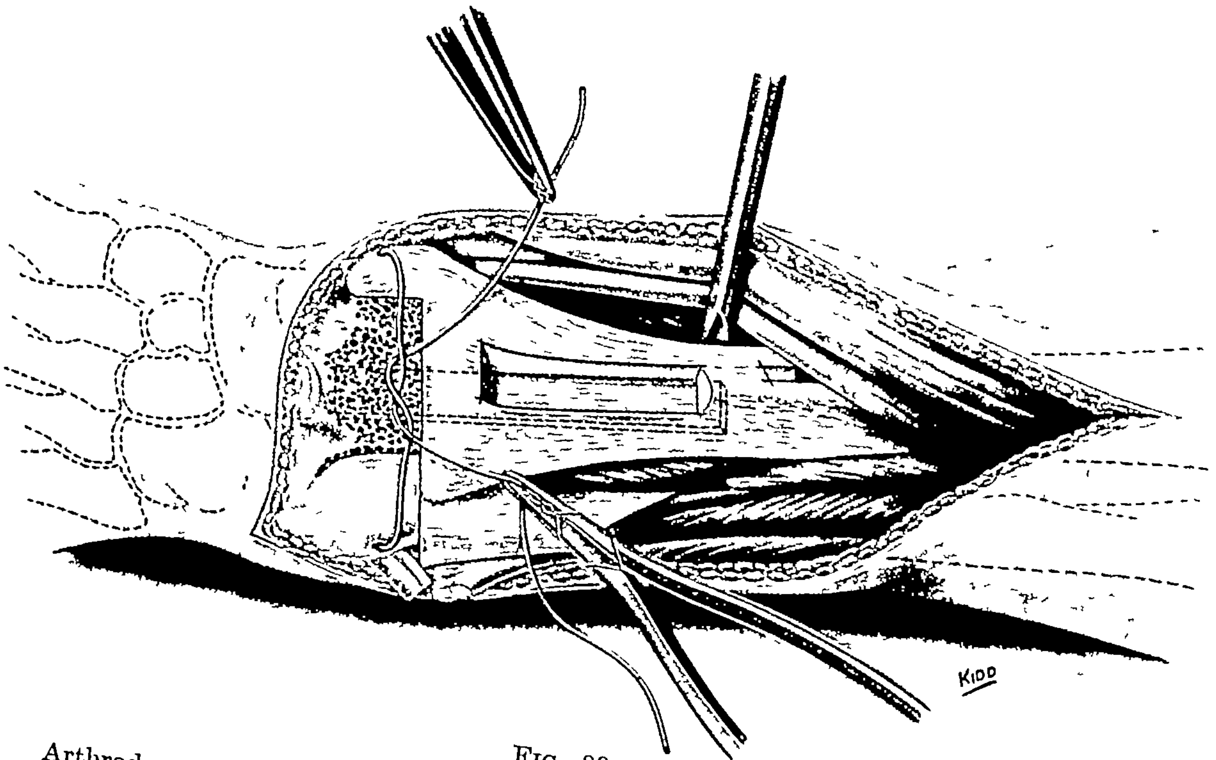


FIG 89

Arthrodesis of the ankle The bail graft *in situ* The kangaroo tendon has been passed through the malleoli and the astragalus and is about to be tied

square, and fitting it into a similar angle between the internal malleolus and the lower surface of the tibia A fibular osteotomy is also performed, and the external malleolus is secured to the astragalus, possibly to the graft, and to the internal malleolus by kangaroo tendon passed through a hole drilled through all these three or four structures

The criticism may be made that such elaborate measures are unnecessary, and that the ankle joint will fuse if the cartilage of the opposing joint surfaces is removed and a fibular osteotomy performed This is possibly true in those types of arthritis where ankylosis is prone to occur, but where disease is present a graft is essential, and burying it completely gives it the best chance of survival

Operation.—An incision is made 6 in long starting over the front of the tibia and curving downwards over the external malleolus and ending $\frac{1}{2}$ in below it The tendons of extensor digitorum longus, extensor hallucis longus and tibialis anticus are identified and retracted to the medial side The ankle joint is identified and the tendons of peroneus longus and brevis are divided An osteotomy of the fibula is performed at the level of the upper margin of the astragalus The ankle joint is now opened through the osteotomy site by pulling the foot forcibly to the inner side The articular cartilage is completely removed from all joint surfaces (Fig 86) The articular surface of the astragalus is cut squarely like a cube of sugar, and the cartilage is removed from the tibia and internal malleolus, so that an angle of 90° is left at the upper and inner angle A gutter is cut in the tibia commencing $2\frac{1}{2}$ in above the ankle joint and ending within $\frac{1}{2}$ in of the joint line. A special curved chisel is now passed downwards in the line of this gutter through the joint into the astragalus for a distance of $\frac{3}{4}$ in (Fig 87) An anterior bridge of tibia is thus left. Measurements are taken from the lowest point of the cavity made in the astragalus to the upper limit of the gutter, and a graft, one end bail-shaped, is cut from the tibia $\frac{1}{4}$ in longer than this The graft is introduced into the gutter and forcibly inserted into the astragalus Its upper end, the bail, is punched down into the tibia so that it is overhung by its upper margin. A $\frac{1}{8}$-in drill is then passed from the outer to the inner side, just below the level of the joint (Fig 88) It

traverses the external malleolus, the astragalus, possibly the graft, and the internal malleolus. Stout kangaroo tendon is passed through the drill-track, and the malleoli and astragalus are firmly lashed together (Fig 89) The peroneal tendons are sutured and the wound closed. Immobilisation in plaster of Paris for four months is necessary

RADIOGRAPHS FOR CHAPTER VII

ARTHRODESIS OF THE ANKLE



Fig 90

Malunited Pott's fracture in a man aged 32 Arthrodesis of ankle Note that the graft has jumped out of tibia at upper end

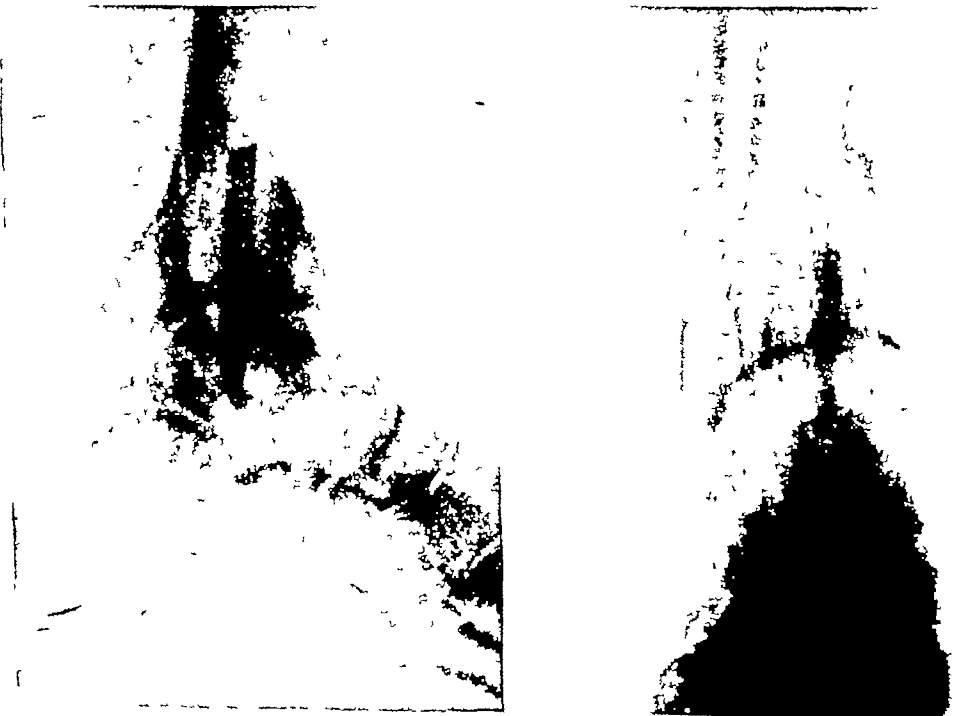


Fig 91

Malunited Pott's fracture in a woman aged 28 Arthrodesis of ankle Firmly fused



Fig 92

Tuberculosis of the ankle in a boy aged 18 Arthrodesis of the ankle Firmly fused

CHAPTER VIII

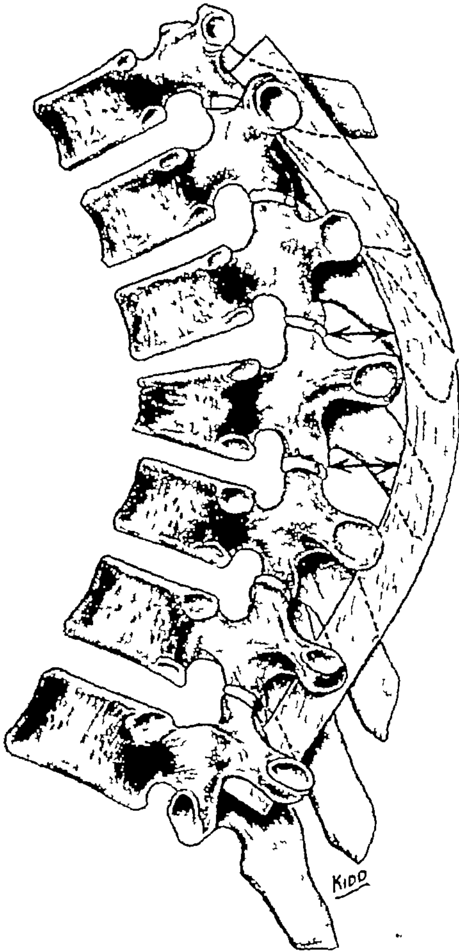
ARTHRODESIS OF THE SPINE

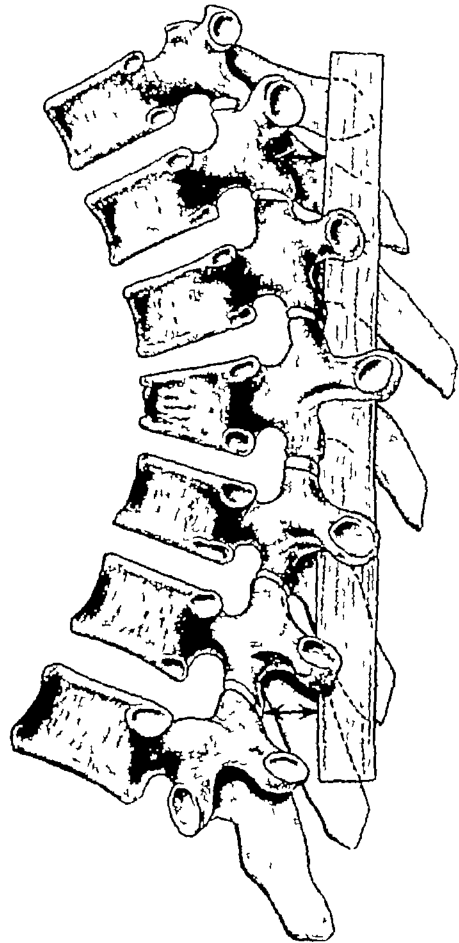
ARTHRODESIS of the spine is practically always extra-articular and posterior, and the main force the graft has to withstand is flexion. Flexion tends to make the spine come away from the graft, and consequently there will be tension between posterior grafts and the anterior column As there are multiple joints above and below the affected area the tension is not necessarily very severe, but nevertheless numerous cases of pseudarthroses and absorption of spinal grafts are seen.

Where a **kyphosis** is present there is difficulty in shaping the graft to become accurately apposed to the denuded laminæ. Grafts may be cut too curved or not curved enough. The former may cause a pseudarthrosis in the centre of the affected area with resulting insecure fusion and progress of disease (Fig. 93). The latter may lead to failure of fusion at either end of the graft or even at both ends (Fig. 94). Possibly too much reliance is placed on the fact that the weight of the recumbent patient in a plaster bed is acting as an additional splint. It is imperative that complete bony union should take place before any strain can be allowed, and it would of necessity have to be more complete than any other form of arthrodesis were it not for the fact that the spine is composed of multiple joints. We have thus two factors functioning: firstly, the tension between the graft and the spine, tending to make the arthrodesis inefficient; and secondly, the multiplicity of the spinal joints minimising the strain at the site of fusion.

It seems, therefore, that the form of fusion which will create the most bone is the most desirable, as tension cannot be avoided. Consequently, the method of using multiple chip grafts appears to be the most suitable, as there is little doubt that large masses of bone are thrown out by this method (Fig. 95). A criticism sometimes made of the use of multiple chip grafts is that they

may die in a large hæmatoma. It is true that after the chips have been placed in their bed, and before the muscles can be sutured over them, some hæmorrhage may take place which may





Arthrodesis of the Spine

FIG 93

Common faults in classical fusion operation Too curved a graft showing pseudarthrosis between the centre of the graft and the spine

FIG 94

A graft not sufficiently curved, showing tension between the graft and the spine at each end and probably pseudarthrosis

cause the grafts to float away from their bed This criticism, however, is met by modifying the method so that the spinous processes are turned up from below, attached by the spinous ligaments and aponeurosis, and later replaced, first removing enough bone from the bases of the spines to make room for the grafts. The principle of adequate protection of the grafts is applied

as far as possible, as these are enclosed by bony surfaces both in front and behind. As observed already, a "sandwich" is formed which consists of the laminæ in front and the spinous processes behind, while the chips constitute the "jam."

Operation.—The operation is performed as in the classical Albee[1] operation except for the following details: The aponeurosis covering the erector spinæ is incised on each side of the spinous

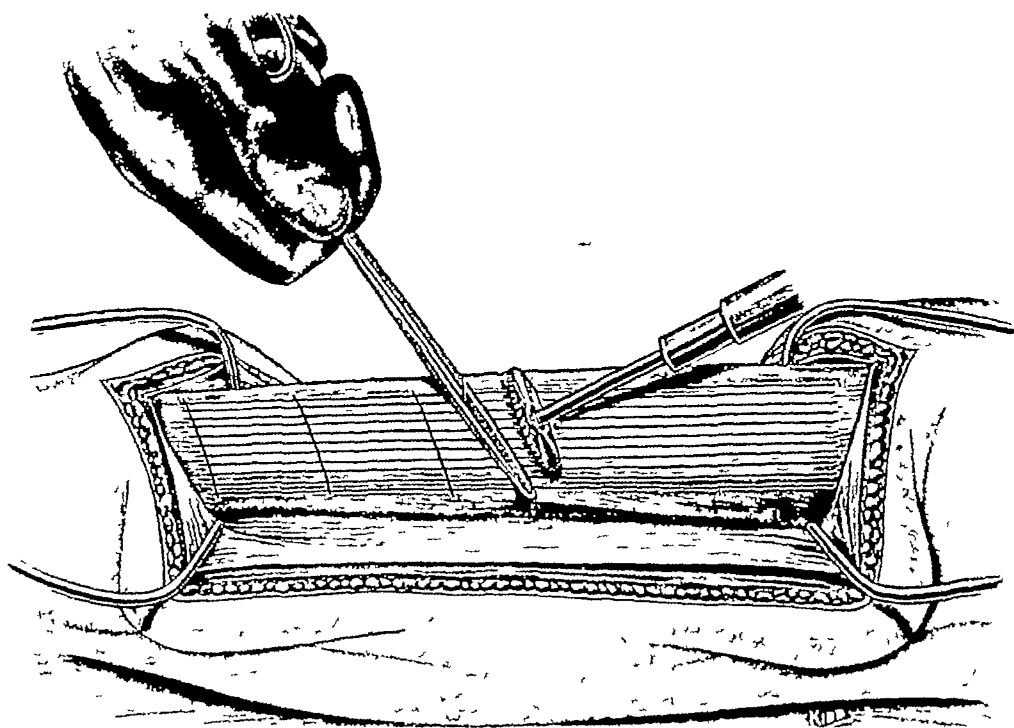


FIG 95

Method of cutting multiple grafts Parallel cuts are made in the tibia about $\frac{1}{12}$ to $\frac{1}{8}$ in apart The assistant must hold the grafts down, as otherwise they may fly out while the transverse cuts are being made

processes throughout the length of the wound, the incisions being separated by $\frac{1}{2}$ in (Fig. 96). The laminæ are denuded of muscle by elevators on each side, as in the operation by Hibbs.[2] The spinous process in the lower angle of the wound is cleared with an elevator on each side and also on its inferior aspect. The processes are divided at their base with bone forceps, starting with the most inferior and proceeding up the wound, the interspinous ligaments and the aponeurosis being left attached. They are reflected upwards in one attached piece at the upper angle

of the wound. The laminæ, which have been cleared laterally as far as the lateral vertebral joints, are roughened with bone elevators (Fig. 97). It may be desirable to remove the cartilage from the lateral vertebral joints also. Where possible the periosteal

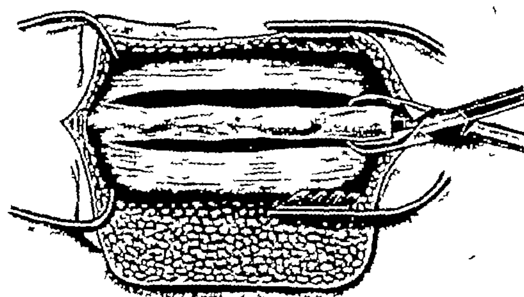


Fig 96

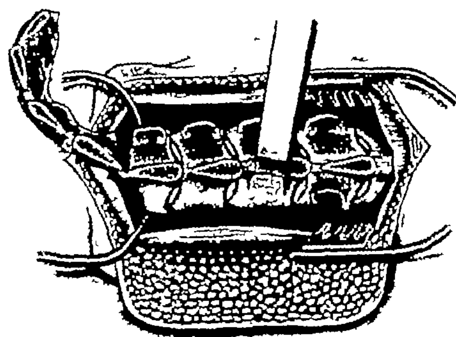


Fig 97

Fig 96—Arthrodesis of the spine An incision has been made through the aponeurosis along each side of the spinous processes and the muscle stripped from these The spinous processes are cut at their base by laminectomy forceps

Fig 97—The spinous processes have been turned up attached to the aponeurosis The cortical bone is being raised off the laminæ but is left attached

surfaces of the laminæ are raised up, but are left attached to the laminæ at the outer margin of the wound The lower half of the bases of the spinous processes are removed and the chip grafts are poured into the prepared bed throughout the length of the wound (Fig 98) Their disposition is important. They should be placed as in Fig 99 with *binding*, as a bricklayer places his bricks Grafts should also be placed at right angles between each vertebra, as this is, of course, the weak point. The processes are then replaced and the aponeurosis carefully sutured on each side, thus enclosing the grafts in their bed and supplying an extra layer of bone on the superficial aspect It might be said that the "lid" is put on the box

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[1] Albee, F H "Bone Graft Surgery" Appleton Century Co New York, 1940
[2] Hibbs, R A *New York Medical Journal*, May 27, 1911

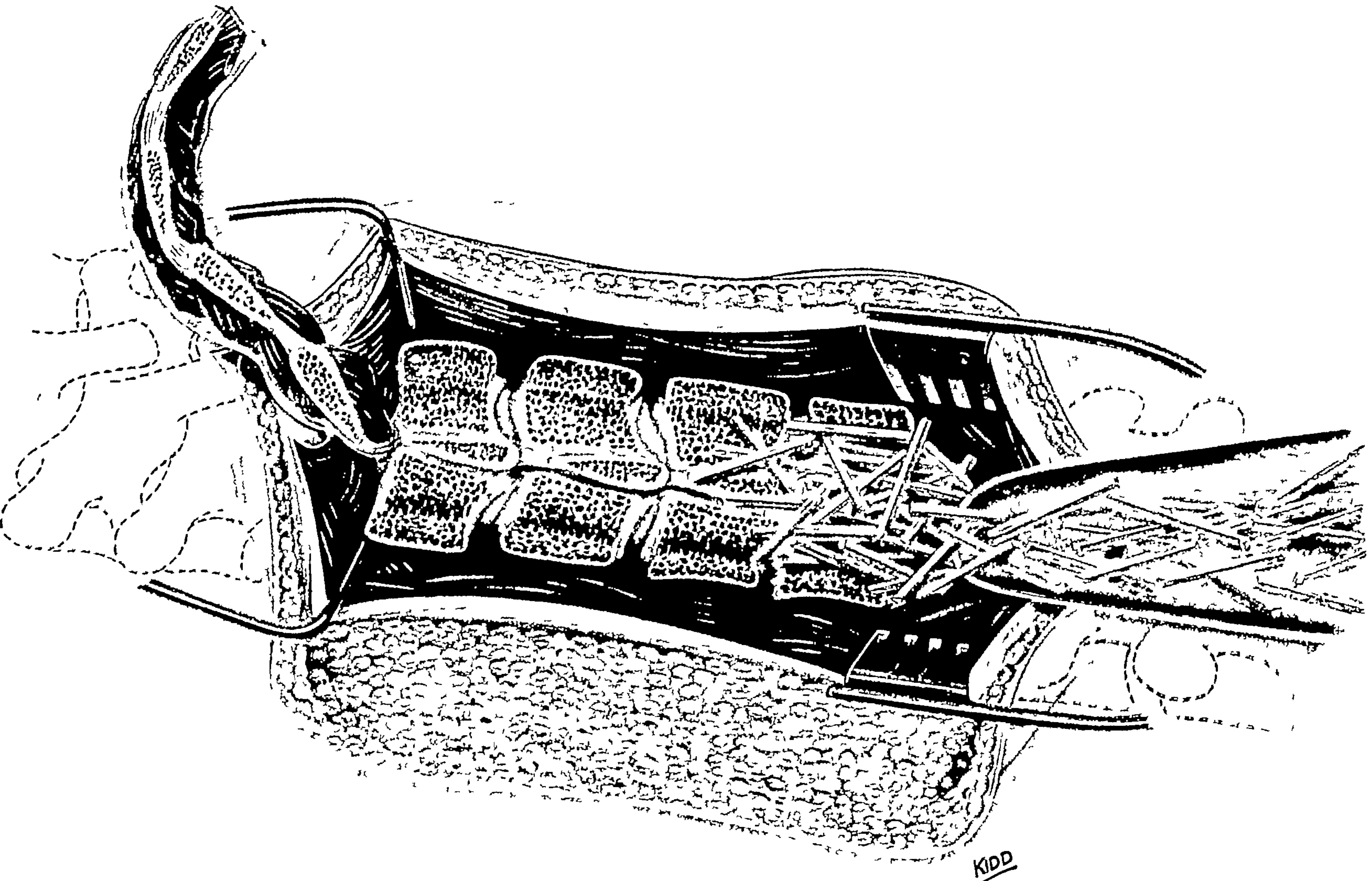


Fig 98

Arthrodesis of the spine The chip grafts have been poured in The laminæ are left raised up at the outer edge and the spinous processes are left attached to the aponeurosis

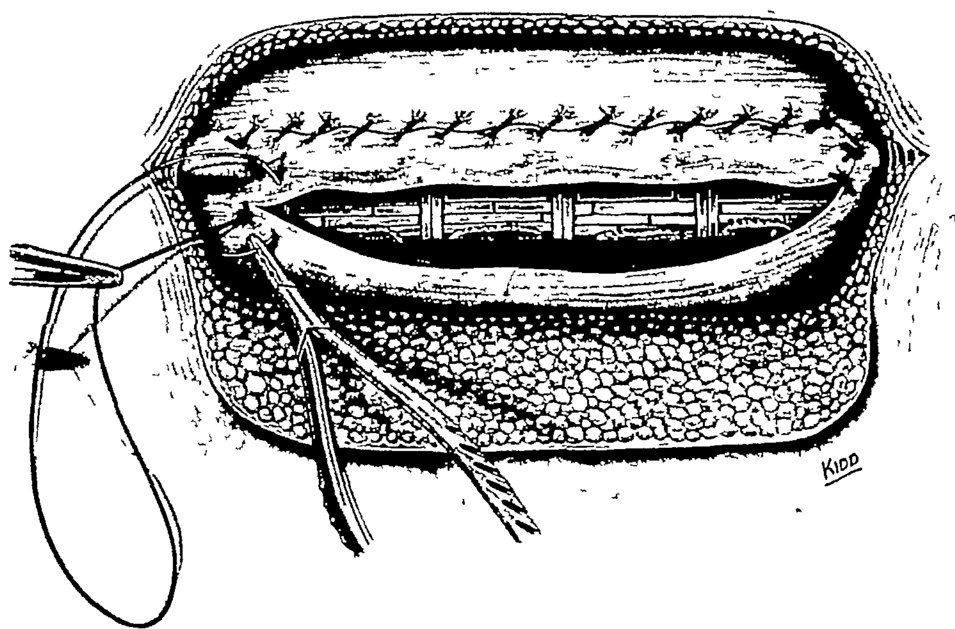


FIG 99

The grafts have been placed *in situ* and the spinous processes replaced on top The aponeurosis is being closed Note the binding of the grafts similar to bricklaying, and the cross grafts on the weak point between each vertebra

RADIOGRAPHS FOR CHAPTER VIII

ARTHRODESIS OF THE SPINE





FIG 100
Compression fracture of spine in a man aged 56 Arthrodesis by clip grafts Note spinous processes enclosing them Fusion is taking place N B—It is difficult to get good lateral pictures of clip grafts except in the lumbar region, because the posterior curve of the ribs interferes



Fig 101

Tuberculosis of the spine in a child aged 8 Six years' history Arthrodesis by chip grafts

CHAPTER IX

ARTHRODESIS OF THE INTERPHALANGEAL JOINTS OF THE THUMB OR FINGER

THESE joints, in the writer's opinion, are actually most difficult to fuse successfully, possibly more difficult than any other Probably arthrodesis here has never been seriously contemplated because there are ten fingers, and amputation as a rule is the simplest solution Actually, however, to a skilled workman or an artist the preservation of a finger, even with a stiff terminal joint, may be of particular importance The thumb, of course, should never be amputated if any vestige of it can be preserved.

By far the most frequent indication is *the neglected mallet finger*, or tear of the extensor tendon at its origin with or without a fracture, but *chronic arthritis of an interphalangeal joint, either infective or degenerative following trauma*, may also call for fusion. The reluctance of one bone to fuse with another, even though the articular cartilages have been removed, has already been remarked upon Nowhere is this demonstrated more consistently than in the interphalangeal joint of the hand. Strangely enough, the toe does not resemble the finger in this respect, for in the ordinary wedge operation for hammer-toe, fibrous union is rare Here, however, some flexion deformity is usually present, and it is only necessary to remove a wedge of bone to get apposition of the surfaces. Removal of sufficient skin generally results in these surfaces being held in adequate contact. The finger, however, should be fixed in slight flexion, and this will increase the interval which removal of the cartilaginous surfaces will leave. It seems essential, therefore, to utilise a bone graft.

Adequate protection of the graft is the chief principle to be demonstrated here, but also **the breadth of the graft is placed in the position of greatest stress**, namely, flexion and extension. The use of a central bone graft might predicate opening out the

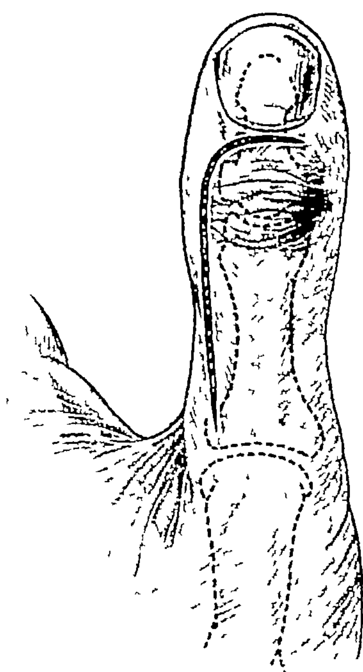


FIG 102
Incision for arthrodesis of the interphalangeal joint of the thumb

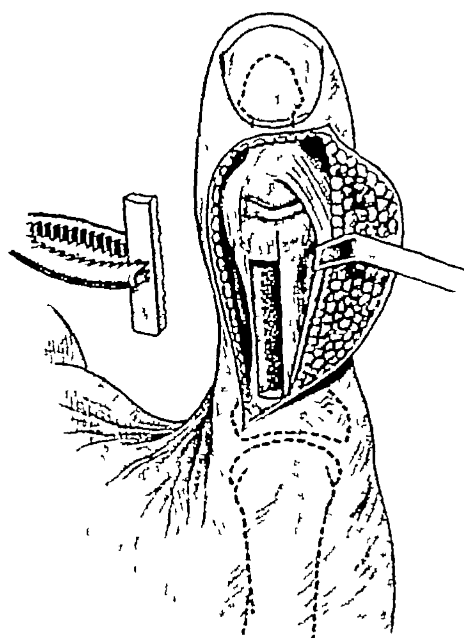


FIG 103
The graft taken from the proximal phalanx Note prolongation upwards from the graft bed into the joint

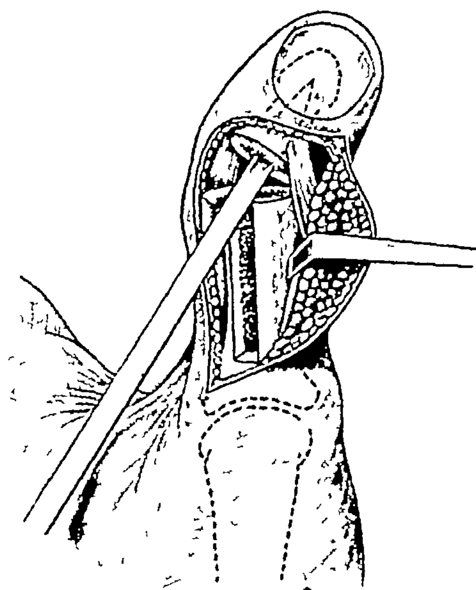


FIG 104
The chisel is passed upwards along the medulla of the terminal phalanx through a small trap door seen open in the proximal phalanx

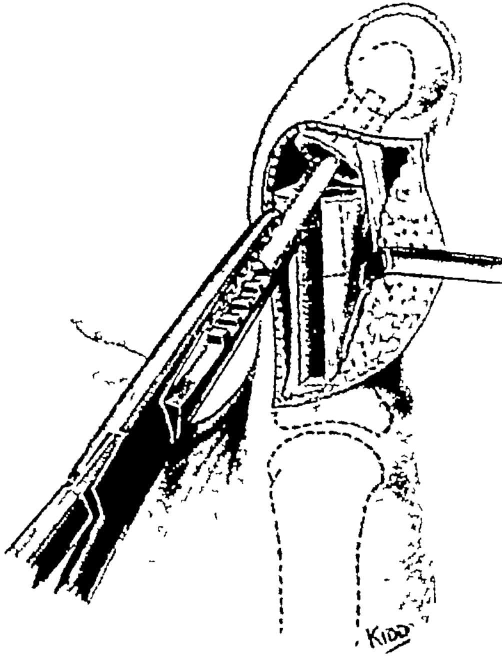


FIG 105

Arthrodesis of the interphalangeal joint of the thumb The graft is passed upwards along the medulla of the distal phalanx and is being guided through a trap-door into the medulla of the proximal phalanx

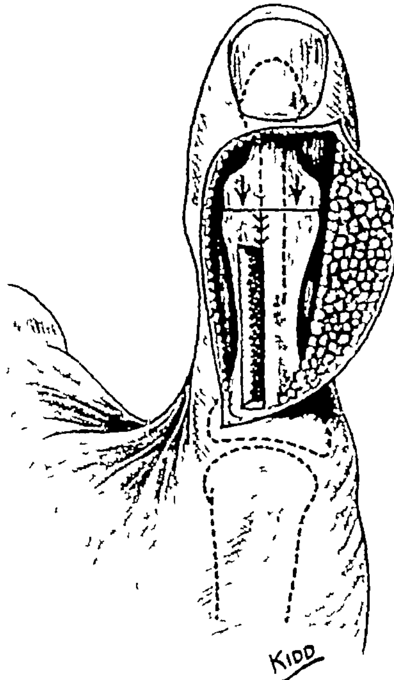


FIG 106

The graft is *in situ* and the phalanges have been forcibly approximated

joint and pulling on the finger to an abnormal extent, reminiscent of the manner in which the old intramedullary bone-pegging operation for non-union was performed To overcome this difficulty a combination of the central bone graft and the inlay cortical graft is used, a trap-door being opened in the proximal phalanx and the graft slid in from the side.

Operation.—The operation is described as for the thumb, but is equally applicable to the terminal interphalangeal joints of the other fingers.

An incision is made commencing on the dorsal aspect of the thumb just below the nail, and curving downwards along the medial border of the thumb for a distance of $1\frac{1}{2}$ in. (Fig. 102) The proximal phalanx is exposed throughout the medial half of its circumference, and a graft $\frac{3}{4}$ in long and the thickness of two match-sticks is cut with a fine osteotome (Fig 103). The intra-articular ligaments are now divided from the medial side and the joint opened laterally The cartilage is carefully removed from each joint surface and a fine osteotome, $\frac{3}{16}$ in. wide, is introduced into the medulla of the distal phalanx for a distance of $\frac{1}{2}$ in to make a bed for the graft (Fig 104). The osteotome is introduced at right angles to the volar and dorsal surfaces of the thumb. The graft is now inserted into the distal phalanx An osteotomy cut is made from the first graft bed in the proximal phalanx up into the joint, and a trap-door hinged out through which the graft is guided (Fig. 105). The phalanges are then forcibly approximated so that their joint surfaces, denuded of cartilage, are in apposition (Fig 106) The finger is put into slight flexion if desirable The wound is closed in the usual way Six weeks' immobilisation will be necessary.

RADIOGRAPHS FOR CHAPTER IX

ARTHRODESIS OF THE INTERPHALANGEAL JOINTS OF THE THUMB OR FINGER



Fig 107 Fig 107

Traumatic arthritis of the thumb resulting from a crush fracture in a serving soldier aged 26 Arthrodesis of the thumb Patient wished the thumb to be fixed in straight position He is now on active service and in category A 1



Fig 108 Fig. 108

Mallet finger caused by injury at work in a woman aged 28 Numerous objective complaints Refused amputation Arthrodesis performed Firmly fused Note trap-door in antero-posterior view through which graft has been introduced The patient has now resumed work

CHAPTER X

ARTHRODESIS OF THE WRIST

A STIFF wrist gives surprisingly good function in the limb provided that the finger movement has not been impaired by pre-existing disease. In many patients it will be possible to preserve the movements of pronation and supination, and willing workmen can easily do heavy manual labour. Complete loss of pain usually results, and as the wrist is not a weight-bearing joint, little strain is thrown on the joint above.

In an old ununited fracture of the scaphoid with advanced arthritis, arthrodesis of the wrist is preferable, in the writer's opinion, to removal of the scaphoid bone, or even the proximal row of the carpus. Pain may be due to either non-union of the scaphoid, or arthritis, or both. Grafting the scaphoid will not cure the arthritis Removal of the scaphoid bone leaves a stiff wrist, frequently weak and frequently painful. Removal of the proximal row of the carpus leaves, in the writer's experience, a very weak wrist indeed. Arthrodesis, however, cures both the pain of non-union and arthritis.[1]

In infective arthritis the disease may become quiescent without complete ankylosis. This movement may be painful. Moreover, the absence of a sound ankylosis almost invariably predicates relapses with acute or subacute exacerbations.

In tuberculous disease conservative treatment must be prolonged, and the results are uncertain. The classical excision of Lister has been advocated, but even if successful, function is very poor. If, after adequate immobilisation and general treatment, there is sufficient regeneration to make arthrodesis feasible, it should be performed. It should not be attempted in a " wet " wrist, that is, where there is gross caseation and pus-formation.

The wrist is subject to a force which may be in any direction,

[1] This was first pointed out by H Osmond Clarke in his Hunterian Professorship Lecture of 1936

but the chief strain that operates is in the direction of palmar flexion. Dorsiflexion and lateral and rotational strains are negligible compared to this It is obviously impossible to remove the cartilage from all the carpal bones, and therefore improbable that an attempt at arthrodesis will be successful unless a graft is used But fusion may be obtained by grafting alone, provided that the graft is stout enough, sufficiently well secured, adequately protected, and subjected to as little tension as possible Most striking is the gradual spread of bony ankylosis from the graft to the other carpal bones at the periphery, even though these have not been tampered with Union, of course, takes place first along

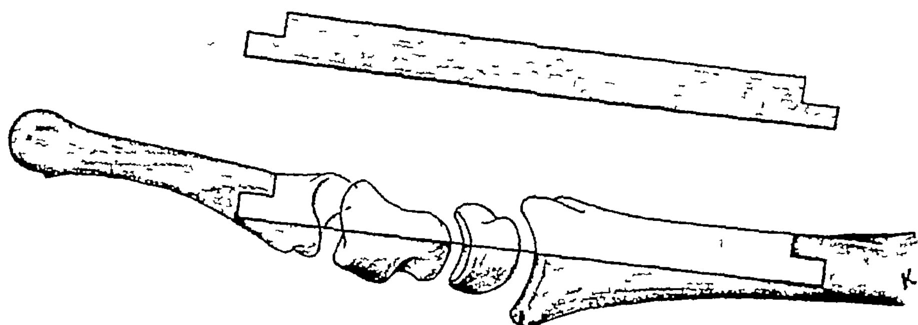


FIG 109

Diagrammatic representation of arthrodesis of the wrist The bail graft fits into the medulla of the radius and the third metacarpal bone and traverses the carpal bones regardless of their identity

the course of the graft, but in some of the earlier cases the wrist has been gradually converted to a solid block of bone.

The graft, as first suggested by Albee, travels from the lower end of the radius to the third metacarpal bone, but it is cut with a step at each end, and the ends fit into the medulla of the radius and metacarpal (Fig. 109)

Three of the four general principles enumerated before are fulfilled to some extent. **Compression in the long axis of the graft** is obtained by pulling on the fingers at the moment of insertion of the graft, so that the soft parts are on the stretch. This, of course, is emphasised when the patient recovers from the anæsthetic and muscle tone comes into action again It is increased by slight dorsiflexion of the wrist, but this must not be overdone, as contact between the middle of the graft and its bed in the carpus may be lost. **The graft is adequately protected,**

as it is fixed in a deep gutter passing from the radius to the metacarpal through the carpal bones, regardless of their identity. This protection is diminished or increased in direct proportion to the activity or otherwise of the disease, for if the carpal bones are caseous they will of course offer no support. As the cancellous bone faces either the radial or ulnar aspect, preferably the radial, **the breadth of the graft is in the position of greatest stress,** namely, palmar flexion

Operation.—A straight incision is made on the dorsal aspect of the wrist joint commencing $3\frac{3}{4}$ in. above the lower end of the



FIG 110

Arthrodesis of the wrist Cutting the bail graft with the electric saw The cuts are made according to the numbers and travel in the direction of the arrows, so that the graft is cut at the expense of the unused tibia and is at no time encroached upon

radius and ending 1 in. distal to the base of the third metacarpal bone The tendons of the extensor digitorum communis are retracted to the ulnar side and the tendon of the extensor pollicis longus is identified, lifted from its pulley and retracted to the radial side. An attempt may be made to preserve Lister's tubercle in order that the pulley-like action of this tendon may continue In practice it will be found that this is difficult and little or no disability results from its sacrifice

A gutter or bed for the bone graft slightly less than $\frac{1}{2}$ in. in breadth is cut, starting from the third metacarpal bone and extending to a point selected on the radius 2 in from its distal end. The bed is cut from the carpal bones regardless of their identity, and no attempt is made to remove their cartilaginous covering other than this. A small chisel is introduced at each end of the graft bed and inserted up the medullary cavities of the

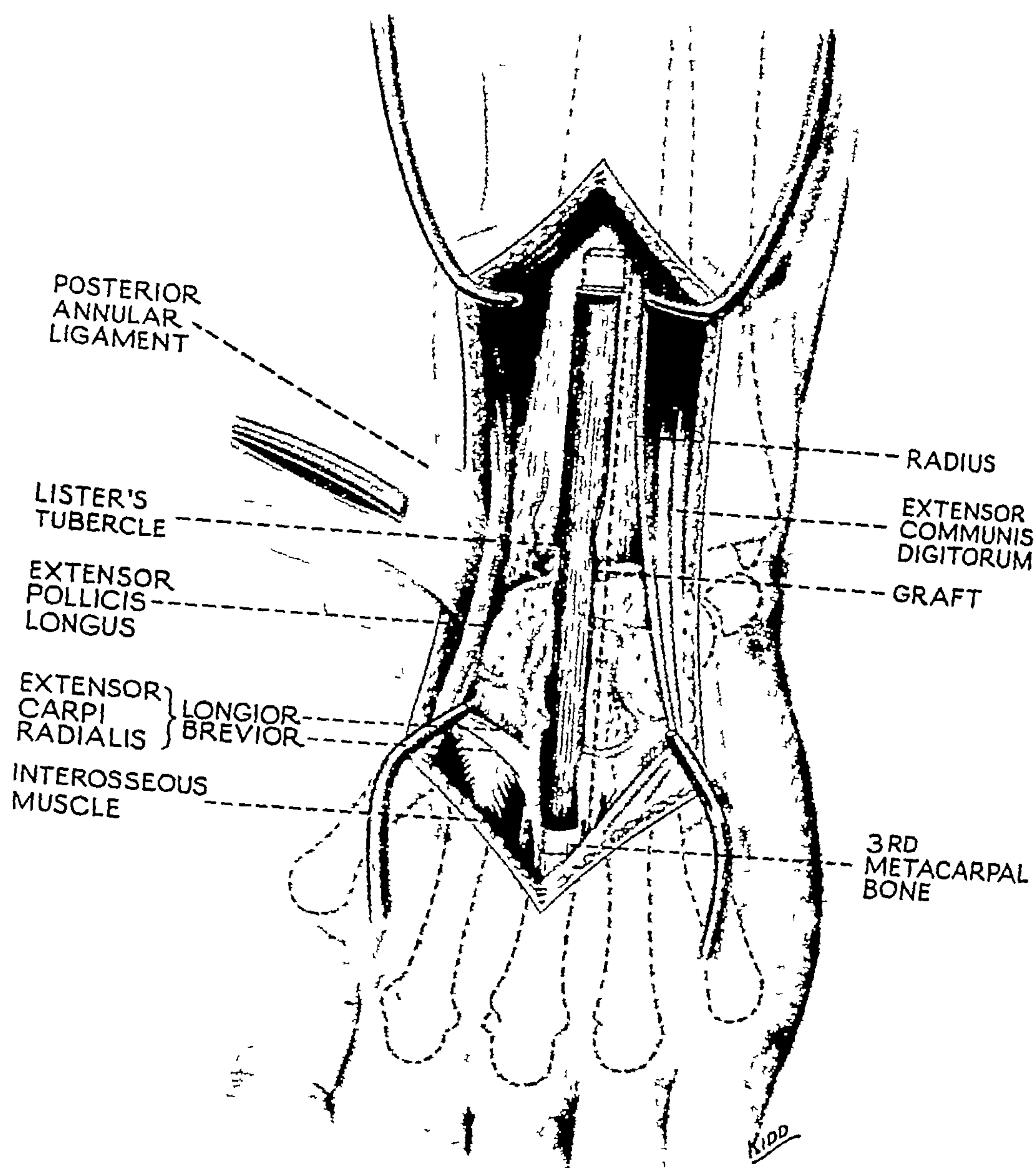


FIG 111

Arthrodesis of the wrist The bail graft is seen well sunk The cancellous side is facing the thumb, so that its breadth is in the position of greatest stress

metacarpal and radius respectively for a distance of ¼ in. The graft should then be cut from the tibia (Fig. 110). It should be cut ½ in. longer than the bed, and should be ½ in. wide. It is introduced into the radius and sunk for ¼ in. into the medullary cavity. Traction is now exerted on the fingers and the graft is levered and dovetailed into its bed in the third metacarpal. When the traction is released the metacarpal should overlap the graft and hold it securely, the step in the graft fitting underneath the undercut portion of the bed at each end (Fig. 111).

At the conclusion of the operation it will be found that the wrist is completely locked by the graft on the operation table. If this is so it promises well for the success of the procedure The limb is immobilised in plaster for four months.

The usual view expressed is that the wrist is a difficult joint to fuse surgically. If this operation is used it becomes the easiest and it is also the most certain.

RADIOGRAPHS FOR CHAPTER X

ARTHRODESIS OF THE WRIST





FIG 112 FIG 113

FIG 112 —Infective arthritis of the wrist in a woman aged 28 Eight years' history Very painful wrist Arthrodesis performed Firmly fused

FIG 113 —Same patient as Fig 112 Lateral view





FIG 114

Same patient as Fig 112 Three years after fusion This patient is employed in a shoe factory and sews thick thongs of leather In spite of apparent fusion between radius and ulna pronation and supination are full

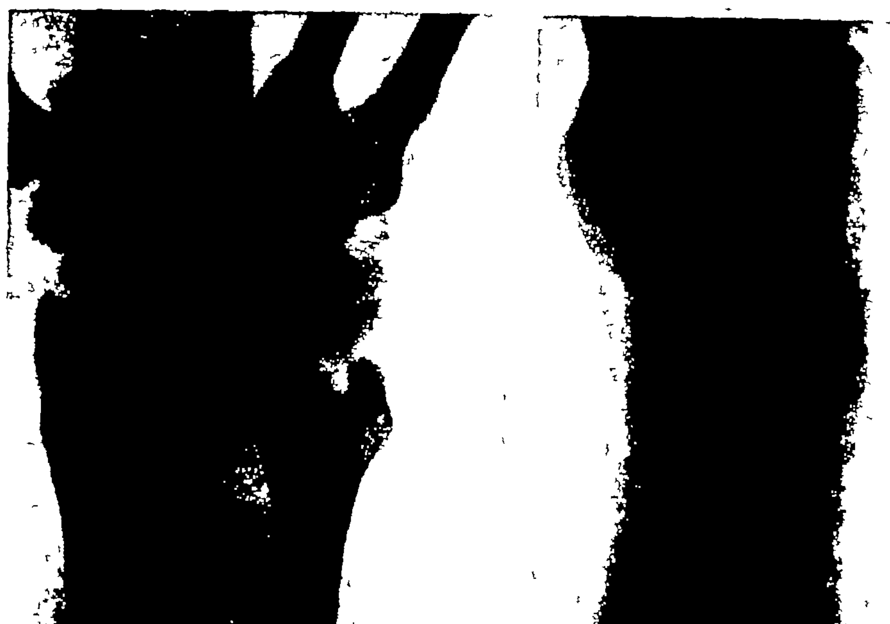


Fig 115

Infective arthritis of the wrist in a man aged 56 Three years' history Firmly fused now Patient has no complaints



Fig 116

Osteo arthritis of the wrist in a woman aged 36. Result of old fractured scaphoid and dislocation of semilunar Firmly fused Lower end of ulna removed Complains of slight pain at this site This procedure is probably inadvisable



FIG 117

Infective arthritis of the wrist in a woman aged 33 Three years' history Operation eighteen months ago Firmly fused Note spread of new bone outwards from the graft

CHAPTER XI

ARTHRODESIS OF THE ELBOW

INDICATIONS for arthrodesis of the elbow joint are few, as arthroplasty usually results in a mobile, painless joint. Occasionally, however, arthroplasty may not be advisable, as, for example, following tuberculous arthritis or infective arthritis where some activity may still be present.

Bony ankylosis is difficult to obtain in the elbow, because two long and powerful levers meet with the greatest stress acting at the joint. Also, removal of the cartilages of the joint surfaces makes close apposition of the bony ends difficult. The fusion occurs between the humerus and ulna only. The movements of pronation and supination should be preserved. These may become limited through fibrosis, even if the radius is not taking part in the actual fusion, so that removal of the head of the radius may be indicated later.

Arthrodesis of the elbow by means of a single graft has proved itself uncertain. The writer attempted an arthrodesis on two occasions, using a single graft passing through the olecranon up into the humerus. In one operation fusion did not occur, 5° of motion being present. The patient expressed himself well satisfied, and wears a leather cast. In the other, bony ankylosis did occur, although a long period, more than six months, of immobilisation was necessary.

The operation which better fulfils the architectural principles emphasised throughout this monograph consists in the use of two grafts which cross at the joint surfaces in the shape of the letter X. The operation does not necessitate exposure of the joint surfaces, as these are traversed by the bone grafts inserted through a very limited exposure. Two tibial grafts are used crossing each other at an angle of about 45°. This angle varies with the angle at which the elbow is fused, according to the requirements of the individual.

In arthrodesis of the elbow it is difficult to place grafts so that the principle of **compression in the long axis of the graft** is obtained. However, by **crossing the grafts in the shape of the letter X the joint is locked.** As gravity tends to extend the elbow, compression of the bone between the opposite angles of the X takes place. Furthermore, the grafts are placed with their cancellous surfaces facing each other, so that **the breadth of the grafts is in the position of greatest stress,** the breadth being *best calculated to withstand stress* (Fig 118).

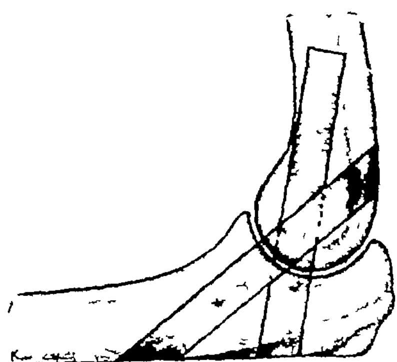


Fig 118

Diagrammatic representation of arthrodesis of the elbow by X grafts The grafts cross each other in the joint line and their breadth is in the position of greatest stress

The operation is a simple procedure, and no important anatomical structures need be encountered. Care should be taken in introducing the second graft from behind so that it does not project too far anteriorly. In experiments on the cadaver it was found that a considerable amount of latitude was possible, because with the elbow in flexion the vessels and nerves in the antecubital fossa were displaced forward.

Operation.—The patient lies on his back with his arm resting on a sandbag on a small table, *the elbow at an angle of 90°.* Two grafts 3 to 4 in. long and $\frac{1}{3}$ in. wide are taken from the anteromedial surface of the tibia in the ordinary way. A longitudinal incision 5 in. long is made over the posterior aspect of the elbow joint, commencing directly over the olecranon and continuing upwards through the triceps in the middle line. The incision is carried down to bone throughout its extent The ulnar nerve is exposed but not disturbed from its bed. Two drill holes, $\frac{1}{8}$ in in diameter, are made in the olecranon process $\frac{1}{2}$ in apart, the first $\frac{1}{4}$ in. from the inner margin of the olecranon and $\frac{1}{4}$ in. from the tip, the second $\frac{1}{2}$ in. distal to this These drill holes are necessary to prevent splitting of the bone, and they are joined together by a clean osteotomy cut. The osteotome is carried up through the elbow joint in the line of the shaft of the humerus, but inclining slightly forwards, for a distance of 3 in. Two similar drill holes are made in the humerus just above the olecranon fossa,

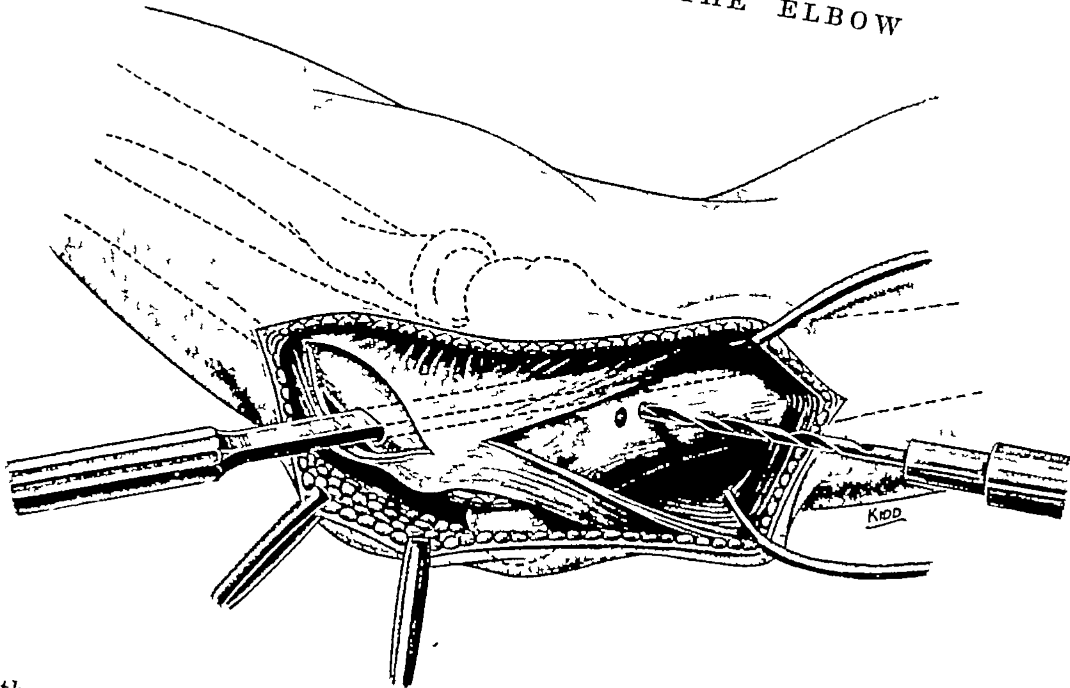


Fig 119

Arthrodesis of the elbow One chisel is in position and drill holes are being made in the humerus for the second chisel The drill holes are made to prevent splintering

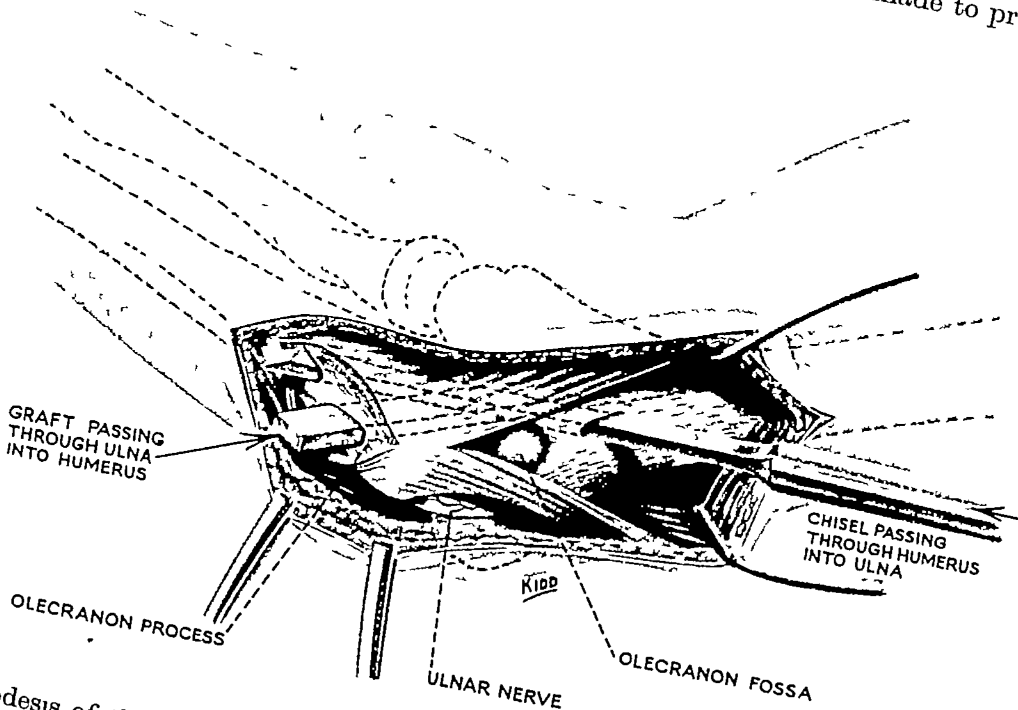


Fig 120

Arthrodesis of the elbow The first chisel has been replaced by a graft which is being driven home When it is *in situ* the chisel passing from above will also be repl[illegible] ft

but to the outer side of the humerus (Fig. 119) Retaining the first osteotome in position, a second osteotome is introduced at right angles to the humerus and in the long axis of the shaft of the ulna, but inclining slightly backwards. The first osteotome is left in position so that the second will avoid it, and consequently the grafts will not interfere with each other in their passage through the bone. It will be found that the elbow joint is completely locked by the two osteotomes The first osteotome is now withdrawn and replaced by a slightly thicker chisel. The chisel is rocked gently to and fro, and when a sufficient space has been made a graft is introduced by bone forceps, and after it has engaged for 1 in or so it is driven home (Fig. 120) Similarly, a second chisel is introduced and replaced by a second graft

Some splintering may occur, as the grafts should fit fairly tightly, but this is controlled by the drill holes But for the danger of splitting the bone, both grafts could be introduced either from below through the olecranon or from above through the humerus, thus requiring a much smaller incision But splintering will undoubtedly occur if this is attempted, and minimising the risk of this is well worth the larger exposure.

Complete fixation in plaster of Paris is usually necessary for four months

RADIOGRAPHS FOR CHAPTER XI

ARTHRODESIS OF THE ELBOW

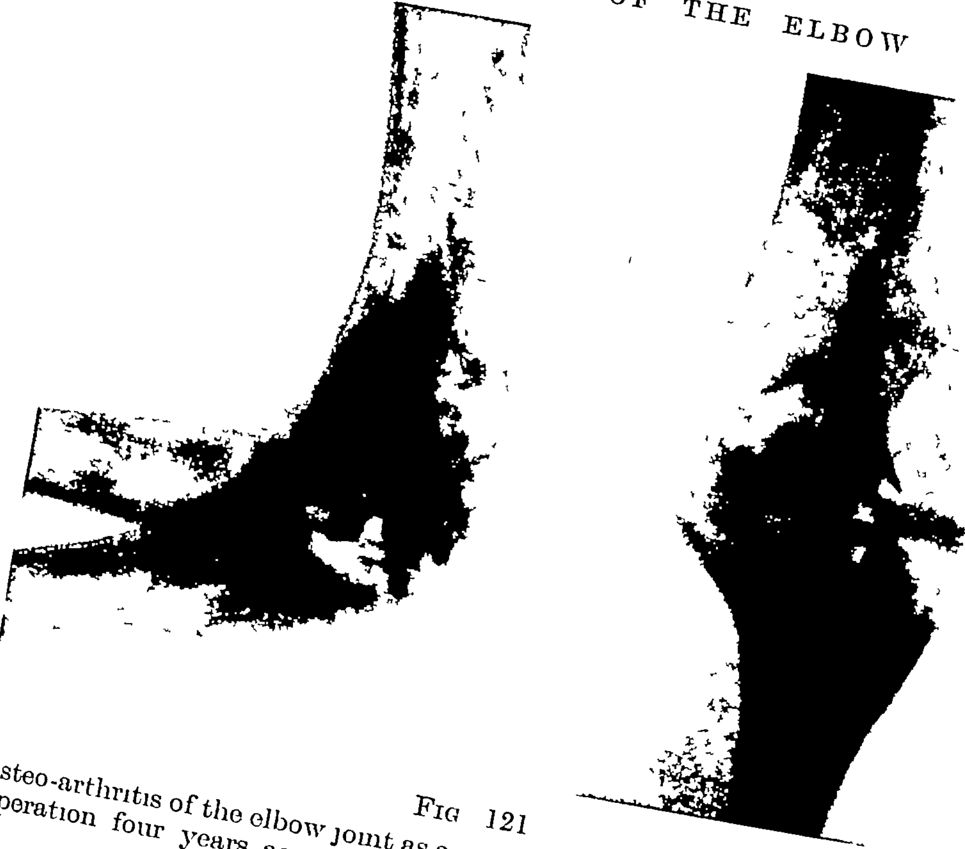


FIG 121

Osteo-arthritis of the elbow joint as a result of old fracture in a man aged 47 Operation four years ago Five degrees of movement present Patient wears a leather cast

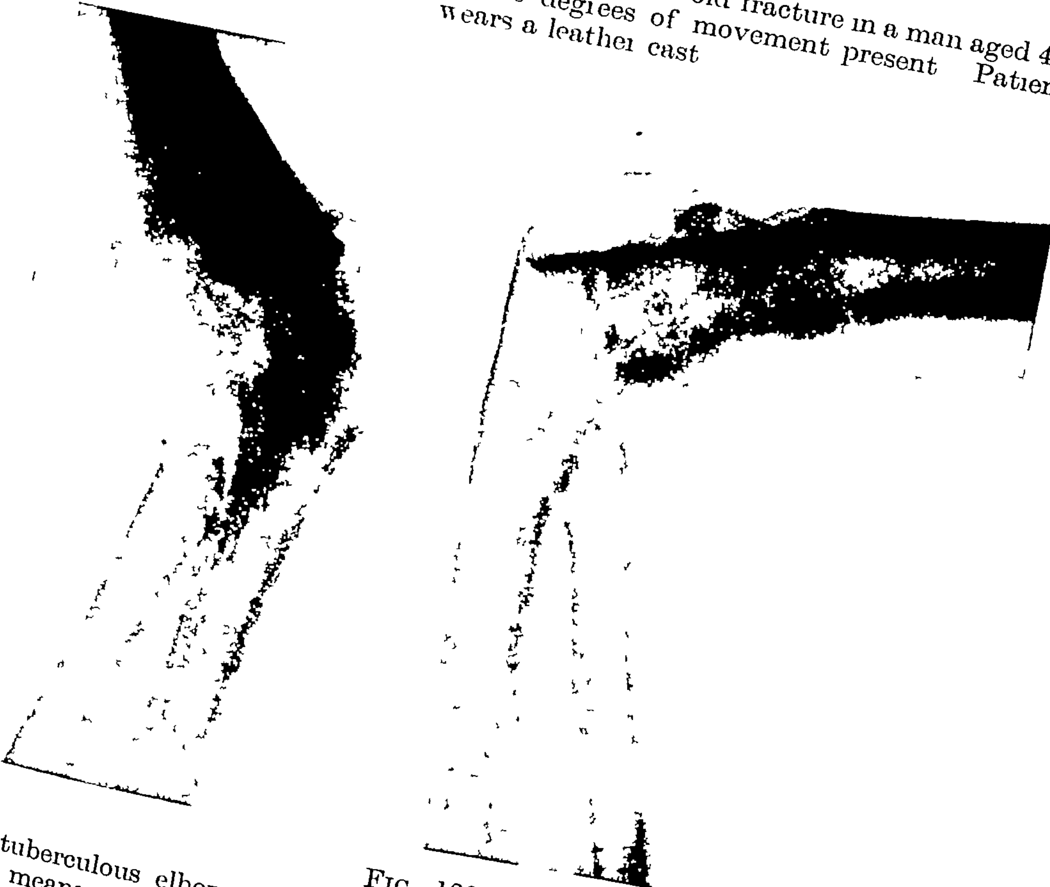


FIG 122

Old tuberculous elbow with sinuses in a man aged 48 Arthrodesis by means of one graft Head of radius removed six months later



FIG 123

Old septic arthritis of elbow in a man aged 37. Arthrodesis using two grafts

CHAPTER XII

ARTHRODESIS OF THE SHOULDER

TUBERCULOSIS of the shoulder is frequently accompanied by pulmonary disease, and therefore conservative treatment may be essential and operations vetoed. Prolonged conservative treatment, however, almost invariably leads to fibrous ankylosis in bad position, with probable sinuses and secondary infection. If arthrodesis can be performed safely (as far as the patient's general health will permit) and efficiently (as far as ultimate fusion is concerned) it is doubtless the best treatment

Many different techniques have been devised for *extra-articular arthrodesis of the shoulder*. These essentially consist of grafting the clavicle and acromion to the humerus above the joint These methods have a limited application, in that extension of the disease in front may make it impossible for the graft to bridge over the disease.

The chief force to guard against in fusion of the shoulder is adduction. In the above operations the grafts—for the acromion and clavicle act as grafts—are in tension, and any adduction of the shoulder will cause separation to occur between the acromion and humerus, with resulting failure of fusion (Fig. 124).

The operation to be advocated for the shoulder is that of **extra-articular posterior scapulohumeral grafting.** This operation fulfils the first architectural principle laid down previously, namely, that **the graft is in compression in its long axis.** It is a procedure analogous to the writer's ischiofemoral arthrodesis, and was first suggested to him by G. K. McKee. It consists of a posterior approach to the shoulder, and the insertion of a massive tibial graft into the humerus below the shoulder joint, and also into the axillary border of the scapula.

In practising the operation on the cadaver the difficulty or impossibility of implanting a graft into a blade of bone such as

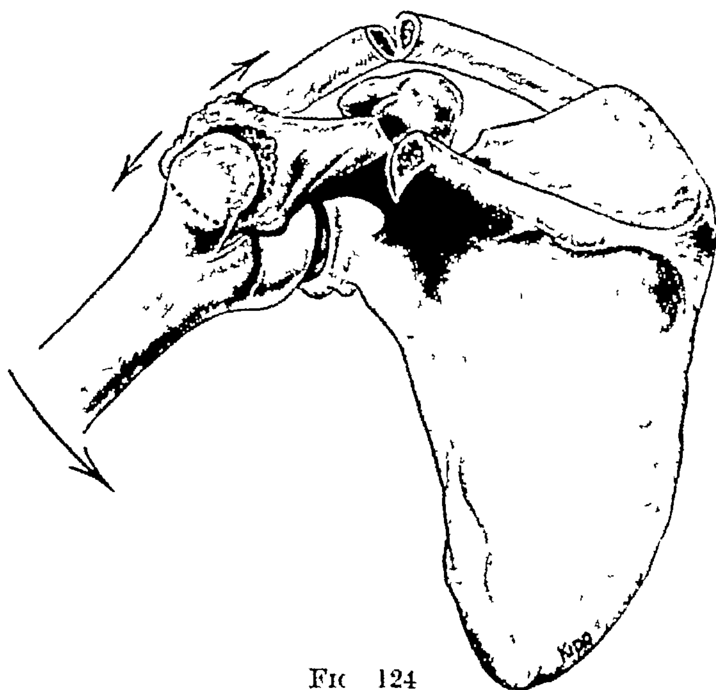


FIG 124

Classical operation of extra-articular arthrodesis of the shoulder using the acromion and clavicle as grafts Gravity exerts a downward force on the arm, so that there is tension between the acromion and the humerus

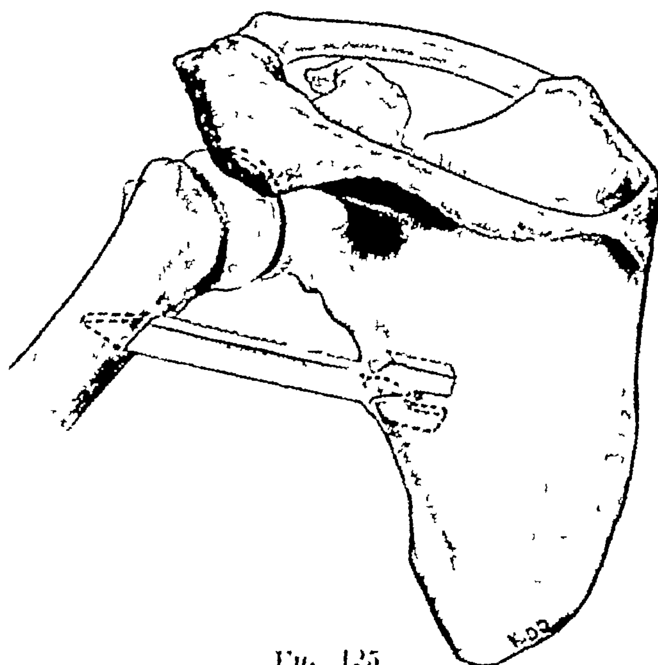


FIG. 125

Posterior scapulohumeral arthrodesis of the shoulder using the arrow graft as described by the writer Measurements of the graft are seen, although these, of course, may be varied to individual requirements

the scapula was realised.[1] This obstacle has been surmounted by cutting a graft in the shape of an arrow with two large limbs at each end and fitting the angle between these limbs into a notch in the scapula. This dovetailing procedure of the writer has proved to be practicable, and in no case has union failed to

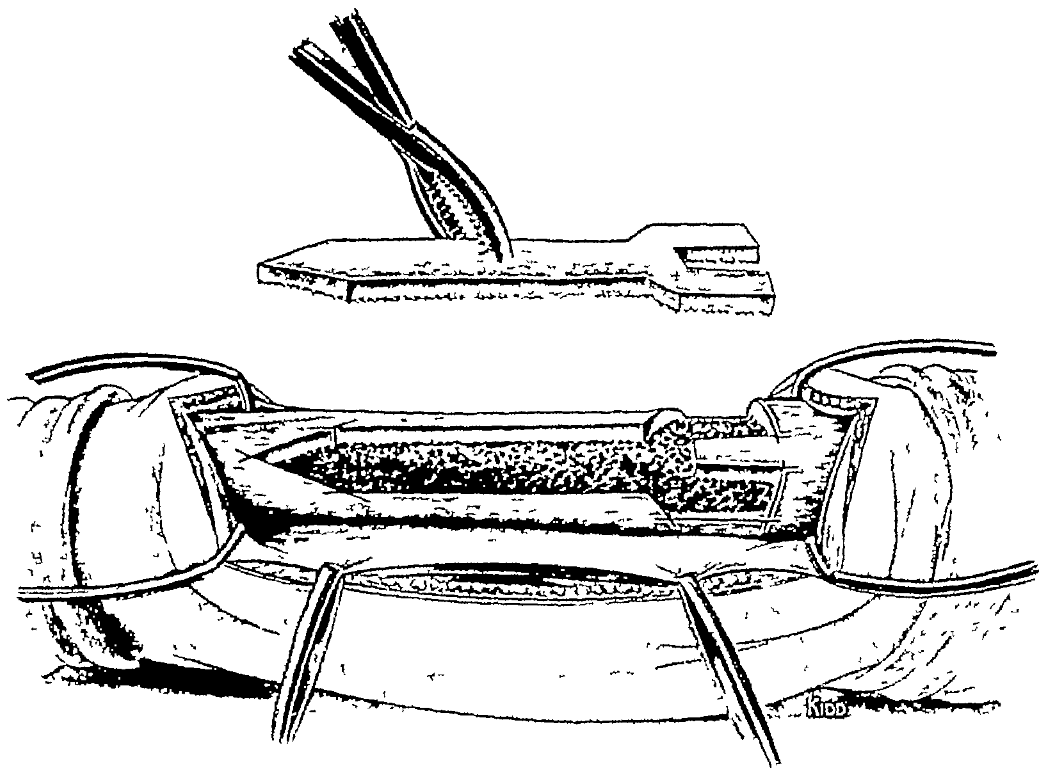


FIG 126
Arrow graft being taken from the tibia The cuts are always made away from the graft at the expense of the tibia which is not being used The notch of the arrow should be taken from the upper end, and the lateral and posterior surfaces may be encroached upon

take place at the scapular end of the graft (Fig. 125). Adduction of the shoulder will always tend to take place in plaster. This will cause **compression of the graft in its long axis,** and make its attachments more secure.

The operation is essentially extra-articular, and no difficulty will be encountered in keeping well below the diseased area

Operation.—A plaster cast is applied to the trunk two days before the operation. The plaster does not cover the affected

[1] This can be done if one separates the origin of the long head of the triceps from the infraglenoid fossa The objections to this, however, are (1) That it is impossible to do so without opening the shoulder joint and thus losing the value of an extra articular operation, (2) the higher up the scapula the graft is inserted the less compression of the graft is obtained, and the less stability, (3) even at best the attachment of the pointed graft in the infraglenoid fossa is insecure, and may easily become dislodged

shoulder or the affected arm. The tibial graft is cut as already described above (Fig. 126), the point of the arrow being 1 in. long, the shaft 4 to 5 in. long and 1 in. wide, and the limbs 1 in. long by $\frac{1}{4}$ in. wide and separated by $\frac{1}{4}$ in. The patient is then turned on to his face. It will be found that with the patient lying on his face and with his arm hanging down, the shoulder will be in a position favourable for arthrodesis, namely, at 90° of abduction and in the neutral rotation position (Fig. 127).

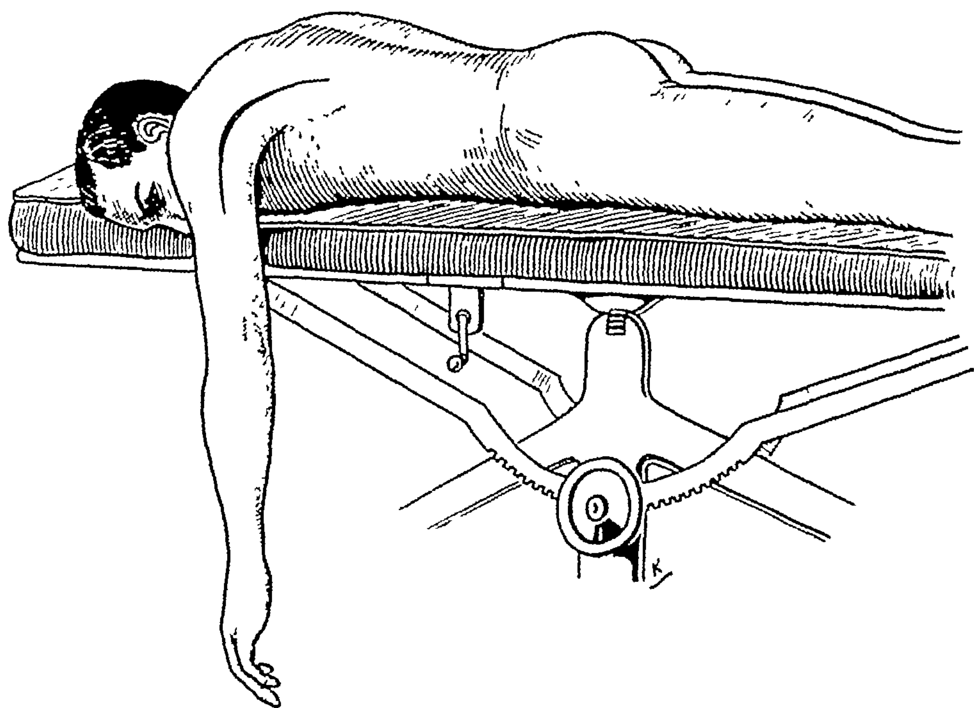


Fig 127
Position of patient for posterior scapulohumeral arthrodesis

The operation site is thus easy of access for the surgeon. As the arm will almost certainly have been allowed to adduct previously, the amount of abduction will be limited.

An incision 7 in. long is made, starting at the posterior margin of the deltoid, passing up over the axilla and proceeding down the axillary border of the scapula to 1 in. from its inferior angle. The lower part of the incision may be started first, and the posterior aspect of the axillary border of the scapula cut directly down to bone (Fig. 128). The teres major and minor are identified, and an incision is made through the latter down to the axillary border of the scapula, which is cleared with bone elevators. The

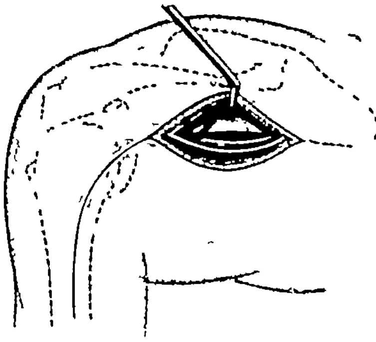


Fig 128

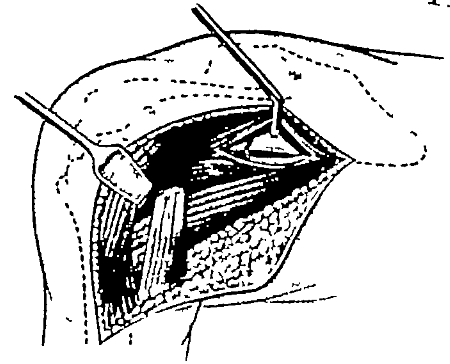


Fig 129

Fig 128—Incision for arthrodesis of the shoulder The teres minor has been incised and the axillary border of the scapula is being cleared The circumflex scapular artery can be seen

Fig 129—The long head of the triceps and deltoid have been identified and the deltoid is being retracted

Fig 130

Arthrodesis of the shoulder The notch is outlined on the axillary border of the scapula The deltoid has been retracted and the medial head of the triceps has been incised and the humerus cleared A hole is being drilled in the humerus

circumflex scapular artery will be seen, and should be divided between forceps. The divided teres minor will fall forward and expose the axillary border satisfactorily The long head of the triceps will be seen arising from below the glenoid (Fig. 129) This should be defined and the interval between it and the posterior border of the deltoid defined and widened In the floor of this interval will be seen the lateral head of the triceps arising from the humerus, and an incision is made through this and the humerus exposed. Two inches of the humerus should be cleared and bone elevators passed round the bone Care should be taken not to prolong this incision too proximally, as the circumflex artery may be severed. The circumflex nerve is not so important, as the shoulder is being fused A drill hole is now made $\frac{1}{4}$ to $\frac{1}{2}$ in in diameter, and an electric drill may be used for this (Fig 130) The aperture is widened by gouges until it is 1 in in length and $\frac{1}{2}$ in in breadth Precise measurements are now taken of the distance the graft has to traverse, and a suitable area on the axillary border of the scapula decided upon A notch is made in this to receive the graft, and this notch should be $\frac{1}{2}$ in in breadth and 1 in in depth. Fracturing the blade of the scapula is not a serious error, as more new bone will be thrown out by this At the same time it should be avoided, as it may make the attachment of the graft insecure The point of the arrow graft is inserted into the humerus first, and then by abducting the arm the graft can be carefully inserted into position so that the limbs fall into the notch in the scapula and grasp the bone (Fig 131) The more difficult this is to do, the firmer will the graft be secured It may be found necessary to divide the long head of the triceps, and if so it should be divided above its nerve supply and sutured in whichever position it lies best, over the graft if possible, so that the latter is covered by muscle The teres minor is sutured and the wound closed in the usual way The plaster is then completed by long slabs on the arm and across the back and chest, with the patient still lying on his face.

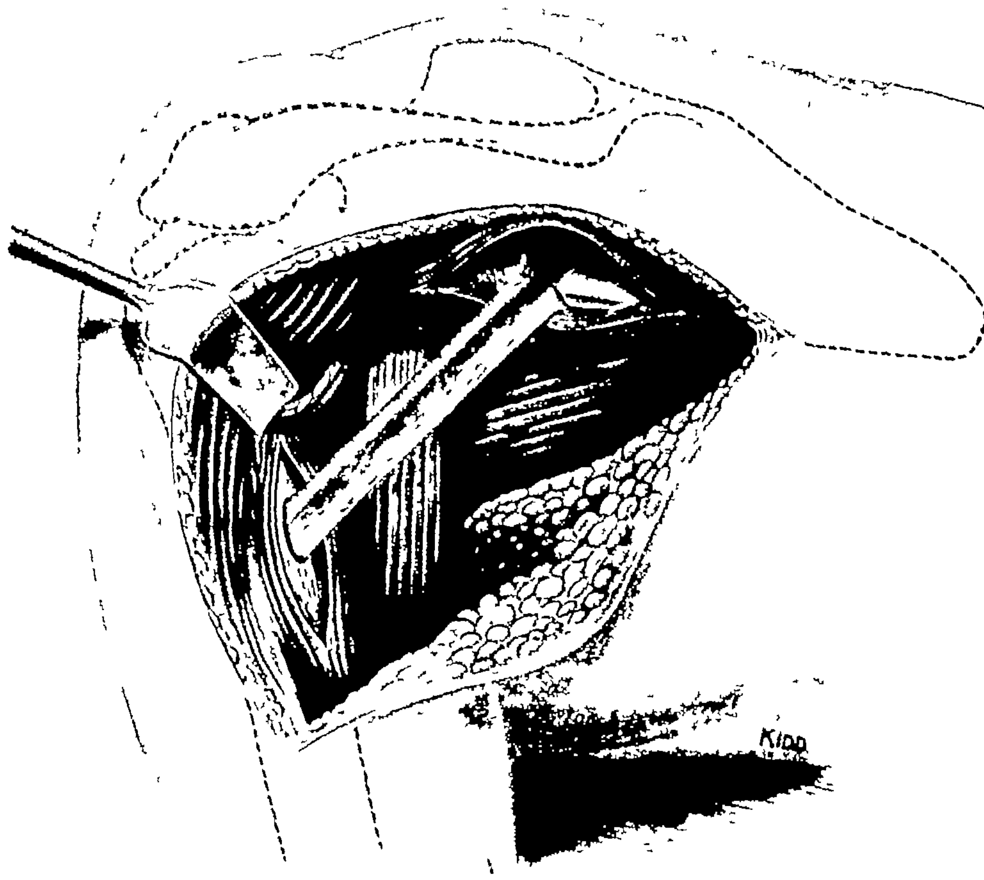


FIG 131

Posterior extra-articular arthrodesis of the shoulder The point of the arrow graft has been inserted into the aperture in the humerus At the other end the graft is notched, and is dovetailed into a similar notch in the scapula The joint has not been opened

RADIOGRAPHS FOR CHAPTER XII

ARTHRODESIS OF THE SHOULDER



FIG 132

Congenital subluxation of the shoulder in a boy aged 17 Radiograph shows limit of abduction



FIG 133

Same patient as Fig 132 Intra- and extra-articular posterior arthrodesis Note increase of abduction Adduction to the side is present



Fig 134



Fig 135

Fig 134 —Tuberculosis of the shoulder in man aged 60, confirmed by aspiration of pus Note rarefaction and bone destruction in region of glenoid

Fig 135 —Same patient as Fig 134 Posterior scapulohumeral arthrodesis Six months after operation Note fusion at scapular end Clinically fused Graft appears thin but is seen on edge



Fig 136



Fig 137

Fig 136 —Same patient as Fig 134 Fracture of graft after undue exertion—"digging for victory" Sinus restarted discharging Arm rested in sling for four months

Fig 137 —Same patient as Fig 134 Shoulder firmly fused Sinus healed



Fig 138



Fig 139

Fig 138—Tuberculosis of the shoulder in a woman aged 32 Note area of caseation in head

Fig 139—Same patient as Fig 138 Twelve weeks after extra-articular posterior scapulohumeral arthrodesis Note angle of humerus to scapula The joint space can still be clearly seen



Fig 140



Fig 141

Fig 140—Same patient as Fig 138 Five weeks later The shoulder has adducted in plaster, as can be proved by comparing it with the previous radiograph Note that the joint space is closing up and that the graft is thicker, i e, it is being compressed in its long axis

Fig 141—Same patient as Fig 138. One year after operation Sound fusion

CHAPTER XIII

APPENDIX TO ARTHRODESIS OF THE HIP

ONE of the great objections to any form of arthrodesis of the hip is the length of time fusion takes and the period of immobilisation necessary. This is of small account in tuberculosis, where frequently previous immobilisation may have amounted to years, and in infective arthritis one can rarely proceed to arthrodesis immediately, as it may occasionally be possible to save the joint by more conservative measures. In osteo-arthritis, however, the symptoms may have occurred so gradually that the patient may feel disinclined to sacrifice at least six months of his time, and few patients will be able to regain their normal activity in any shorter period than this—in fact, it will usually be a year before the patient has become accustomed to the stiff hip and before the knee is fully mobilised Also, elderly patients may not be able to tolerate the long immobilisation in plaster, even though they will probably survive the actual operation of ischiofemoral arthrodesis without much grief.

In these two factors, therefore, namely the shortening of the period of immobilisation and the widening of the age-limit of the operation, lies the chief value of arthrodesis by a Smith-Petersen nail alone, as first described by Burns.[1] In practice, however, it has been found that arthrodesis by a Smith-Petersen nail alone does not produce as high a proportion of successful fusions as even the formal iliofemoral operation, and frequently these patients relapse after what has seemed at first to be a success. Rarefaction may take place around the nail and allow a little movement, and this movement may become very painful indeed. Even the least successful, however, get relief from pain for a period of six months.

An operation has been devised by the writer that takes advantage of this period of, at the worst, temporary immobilisation, combining it with an ischiofemoral graft but without

performing an osteotomy of the femur. The operation is frankly experimental and has only been performed on one patient. Already there seems to be no doubt that this patient has fused, and this appears sufficiently gratifying to offer a further field of investigation.

The operation consists of performing a Smith-Petersen nail arthrodesis, and also passing a fibular graft under X-ray control through the femur into the ischium *without performing an osteotomy of the femur.* A triangle is thus formed that consists of the Smith-Petersen nail, the fibular graft and the pelvis, and the duplication of the struts used prevents movement taking place. In any event immobilisation conferred by the Smith-Petersen nail should be sufficient to allow union to take place at each end of the fibular graft.

Technique of Operation.—A fibular graft is taken 4½ in. long, preferably from the opposite leg. The feet of the patient are fixed with plaster of Paris to the footpieces of an orthopædic table, the pelvic rest consisting of a casette holder. The hip is put in the position considered suitable for arthrodesis, deformity being corrected as far as possible. Opinions vary about this, but in old-established osteo-arthritis it has not been found possible to correct fully the external rotation, while the adduction will usually come out after tenotomy of the adductor longus.

Three Michel clips are placed on the skin over the head of the femur, one at its upper margin, one over the centre of the head and one at its lower margin. The external landmarks for these are a point 1 in. below and internal to the anterior superior iliac spine, the mid-point of a line joining the anterior superior iliac spine and the symphysis pubis and a point 1 in. lateral to the upper margin of the symphysis pubis. Two further clips are placed over the great trochanter, the upper being 1 in. from its tip and the lower 1 in. below this. Two calibrated guides are passed anterior to the neck, starting from the most lateral clips and passing in front of the neck in the line of the medial clips. Anteroposterior and lateral radiographs are taken, and the position of the guides checked and, if necessary, altered. Drill holes ¼ in in diameter are now made in the cortex of the great trochanter, ½ in. below and parallel to the calibrated guides. The lower of the two apertures will have to be made large enough to

receive the fibular graft, and the electric drill will be necessary for this The drill will be carried on through the shaft of the femur until it hits the opposite cortex. After it has pierced this a blunt chisel is substituted for it, and this is passed on in the direction of the lower pair of clips until it encounters the ischium. It is driven into the ischium for ½ in and then rotated, so that an opening is made in the ischium. Non-calibrated guides are now introduced and kept on the line of the calibrated ones and parallel to these in the lateral plane, provided that the position of the latter, previously checked up upon, is satisfactory Antero-posterior and lateral radiographs are now taken, and if the position is satisfactory the Smith-Petersen nail first and the fibular graft second are introduced over the guides and hammered home.

The operation, on the one occasion it was performed, took one and a half hours, but it is felt that this time could be considerably shortened Only a very small incision 3 in long was necessary, and hæmorrhage and shock were negligible Some difficulty was experienced in deciding when the ischium had been sufficiently penetrated, and it is considered that this might be done more easily with a cannula and trocar, the cannula being passed in until it is in contact with the ischium, and then the trocar, graduated at the upper end and of a size similar to the fibula, could be punched home

This operation is presented with a certain amount of diffidence, and it is only due to special circumstances that it has been included with so little practical experience.

REFERENCE

[1] Burns, B H *Lancet*, vol i, p 978, 1939

RADIOGRAPHS FOR CHAPTER XIII

APPENDIX TO ARTHRODESIS OF THE HIP



FIG 142

Osteo-arthritis of the hip in a man aged 66 Unsuitable for femoral arthrodesis

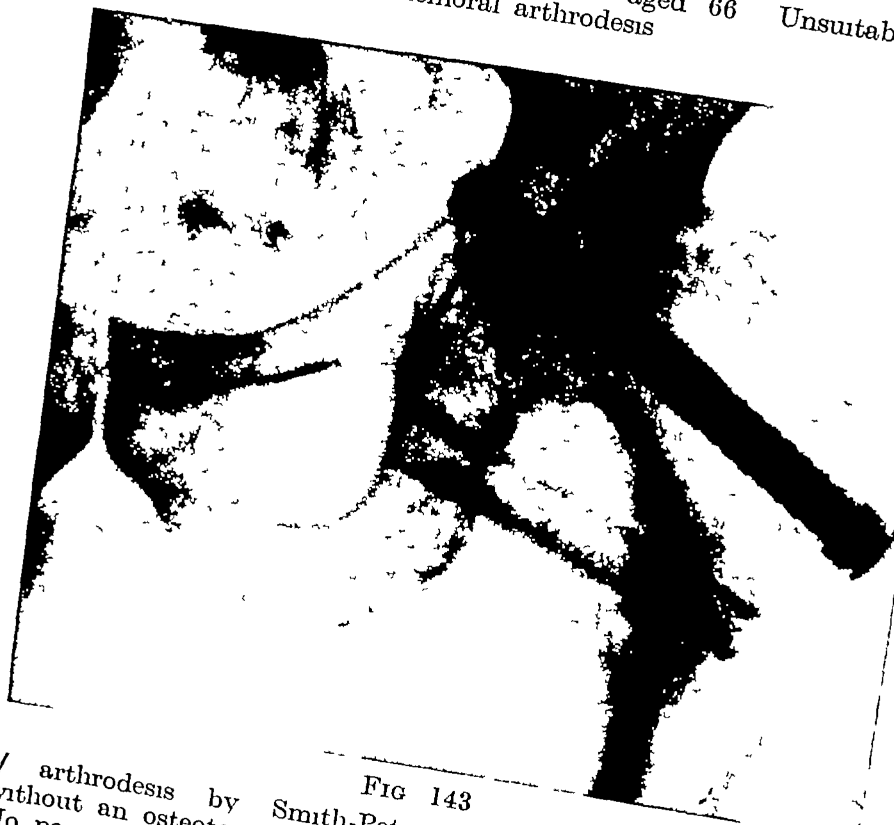


FIG 143

V arthrodesis by Smith-Petersen nail and femoral graft without an osteotomy of the femur Six weeks after operation No pain Hip firmly fixed Fusion appears to be taking place The nail should of course have been placed more vertically



FIG 144

Radiogram taken twelve weeks after operation shows little change The hip appears to be fused The patient has no pain

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